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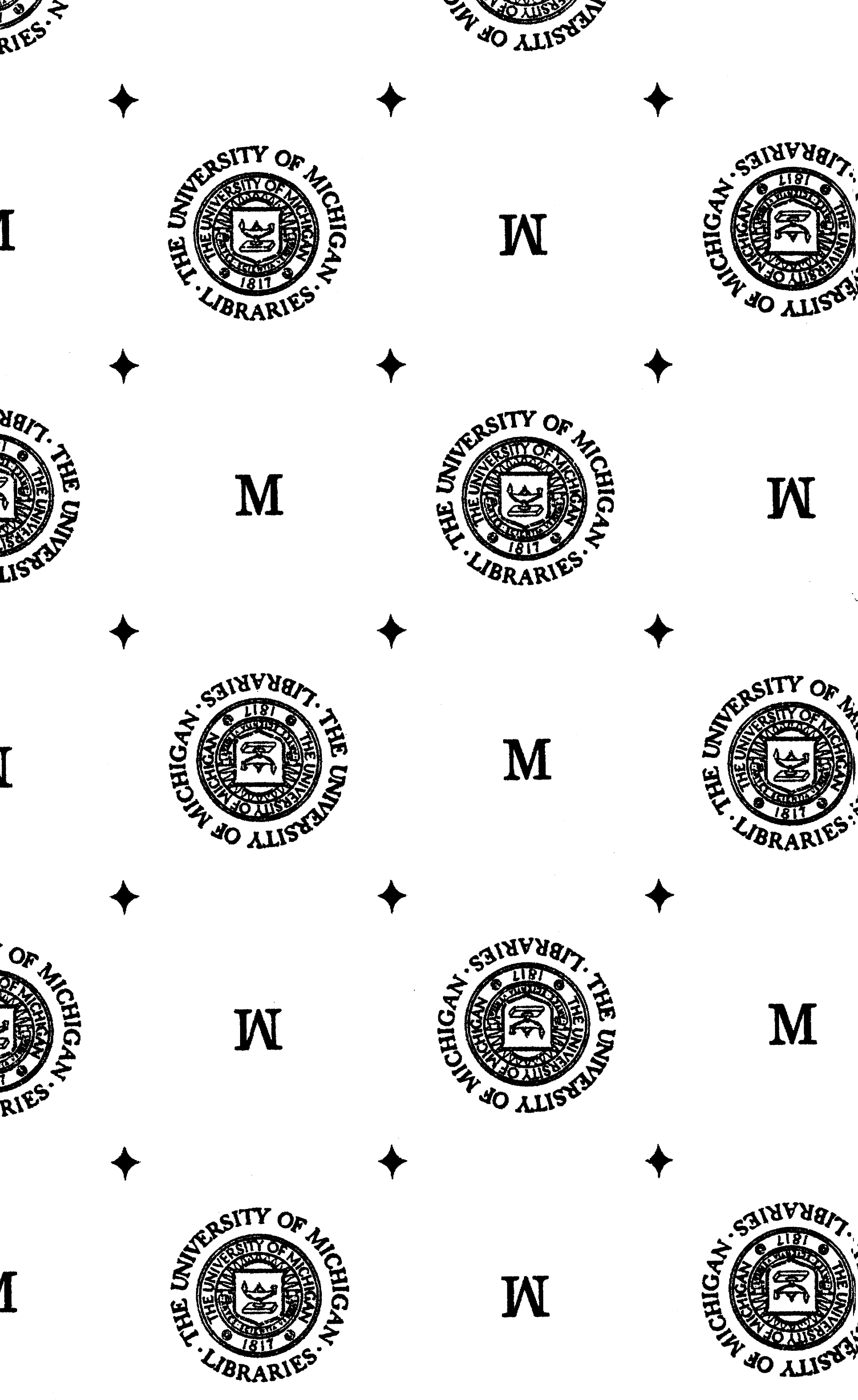

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Issued September 9, 1907.

HAWAII AGRICULTURAL EXPERIMENT STATION,

JARED G. SMITH, SPECIAL AGENT IN CHARGE.

ANNUAL REPORT

OF THE

HAWAII AGRICULTURAL EXPERIMENT STATION

FOR

1906.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

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HAWAII AGRICULTURAL EXPERIMENT STATION.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

STATION STAFF.

JARED G. SMITH, *Special Agent in Charge.*
D. L. VAN DINE, *Entomologist.*
——— ———, *Chemist.*
J. E. HIGGINS, *Horticulturist.*
F. G. KRAUSS, *In Charge of Rice Investigations.*
Q. Q. BRADFORD, *Farm Foreman.*
C. R. BLACOW, *In Charge of Tobacco Experiments (P. O., Paauilo, Hawaii).*

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LETTER OF TRANSMITTAL.

Hawaii Agricultural Experiment Station,
Honolulu, Hawaii, April 1, 1907.

Sir: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year 1906.

Respectfully,
Jared G. Smith,
Special Agent in Charge.

Dr. A. C. True,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. True, *Director.*

Publication authorized.
James Wilson,
Secretary of Agriculture.

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ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1906.[a]

SUMMARY OF INVESTIGATIONS.

By JARED G. SMITH, *Special Agent in Charge.*

The Hawaii Experiment Station has continued the policy of devoting its energies toward the diversification of agriculture in the Hawaiian Islands. During the period that has elapsed since the establishment of the station a number of agricultural industries have been begun or placed on a paying basis. Pineapple growing has been extended to include many large tracts, sisal production has been shown to be profitable, and tobacco raising has been demonstrated as practicable. In all of these enterprises the station has had a part, and the tobacco industry when developed will owe its inception to the investigations of the station.

Considerable work has been done in bringing more of the station land under cultivation in anticipation of the new water system provided for by Congress. About 10 acres of the lower portion of the station tract were cleared, fenced, plowed, and prepared for planting. As the station does not expect to plant all this at present, half the tract was cleared by the Territorial department of public works for the privilege of growing forage plants for a few seasons. In this way the station was relieved of the expense of removing a dense growth of lantana and guavas. The trial grounds of the station were completely fenced and a new slat greenhouse was constructed for the use of the horticulturist. A new stable was erected and a considerable amount of water pipe laid. An additional area, amounting to about 2 acres, on the higher portion of the station grounds was cleared and terraced by Japanese tenants at no expense to the station. The office and laboratory equipments were increased and numerous additions made to the station library by purchase, exchange, etc., so that now the station possesses the best collection of reference books on economic agriculture in Hawaii.

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[a] This is the sixth annual report of this station. Previous reports will be found in U. S. Dept. Agr., Office of Experiment Stations Ann. Rpts. 1901, pp. 361–379; 1902, pp. 309–330; 1903, pp. 391–418; and 1904, pp. 361–382, and Bul. 170. A preliminary report on the agricultural resources and capabilities of Hawaii was published as Office of Experiment Stations Bul. 95.

FIELD WORK AND PLAT EXPERIMENTS.

POTATOES.

An attempt was made to demonstrate the possibility of growing early potatoes for the local market. About one-half an acre of land newly cleared of guava and lantana was planted to potatoes early in January, 1906. The plants were severely attacked by a form of rot and a very short yield was obtained. The crop was readily disposed of as new potatoes at 5 cents per pound, and the demand far exceeded the supply, thus demonstrating the presence of a local market capable of considerable development.

ROSELLE.

An experimental planting of roselle (*Hibiscus sabdariffa*) has been made each season for several years to demonstrate the value of this fruit for preserving, and to study methods of cultivation, insect enemies, and diseases. About one-fourth of an acre was grown this year, and a larger planting was made to carry the experiments through the coming year and to provide material for dissemination.

COTTON.

Several varieties of cotton were grown experimentally at the station during the past year, namely, Peruvian, from seed received from Mr. T. F. Sedgwick, formerly connected with the station, Carolina Prolific, Excelsior, Extra Long Staple, Sea Island, Russell Big Boll, Texas Bur, and King. The yield of the Upland varieties was not especially promising, but for the Peruvian and Sea Island the quality was good and the yield large. Samples of the different lots were submitted to the experts of the United States Department of Agriculture at Washington, and Mr. E. B. Boykin reported upon them as follows:

No. 1, Peruvian, seed from T. F. Sedgwick.—The length of lint of this specimen ranges from 1⅛ to 1⅝ inches; strength good; uniformity poor, the fibers very coarse to very fine, showing great variability in this respect. The drag is very strong, showing that the fibers are very crinkly, and should therefore possess good spinning qualities. The covering on the seed is remarkably heavy, indicating a very high per cent of lint. One fact which detracts from the value of this specimen is the very great variability in length and fineness of lint. Some locks are almost equivalent to the fineness of Sea Island, while others are no better than very ordinary Upland. It seems to afford an excellent opportunity for improvement by selection.

No. 2, Carolina Prolific.—Length of fibers from ¾ to 1 inch; uniformity fair; fineness medium; drag weak; strength poor; covering poor. This specimen should be classed as a rather poor Upland variety.

No. 3, Excelsior.—Length ¾ inch to 1⅛ inches; strength fair; uniformity very good; drag weak; fibers coarse; covering fair. This should also be classed as ordinary American Upland short staple.

No. 4, Extra Long Staple Sea Island.—Length of fiber 1½ to 2 inches; strength excellent; uniformity good; fineness excellent; drag strong; covering poor. The lint in this case is unusually fine. It seems to be quite as good as Sea Island.

No. 5, Russell Big Boll.—Length 1 to 1⅛ inches; strength poor; uniformity fair; fineness very poor; drag fair; covering fair. This should be classed along with some of the poorest short-staple varieties. The extreme coarseness of its lint is a very serious defect.

No. 6, Texas Bur.—This sample is very similar to No. 2, and can only be classed as an ordinary Upland.

No. 7, King.—Length ⅞ to 1 inch; strength poor; uniformity fair; fineness very poor; drag weak; covering fair. This sample is an American Upland variety which is noted for its short, coarse lint, and which is adapted to the manufacture of coarse goods only.

THE ORCHARD.

An orchard of tropical fruit trees, including mangoes, avocados, bread fruit, cherimoyer, sapodilla, wi, custard apple, longan, and others, has been planted and will be extended as rapidly as seedlings or valuable varieties can be obtained. A nursery of citrus stock has been established to provide material for budding and grafting. The uncertainty of the station's water supply has in the past made permanent plantings impossible, but with the special appropriation provided by Congress it is believed that a supply of water will be developed sufficient to care for all the fruit trees planted on the lower portion of the station grounds.

MISCELLANEOUS.

Plantings have been made of about 4 acres of coffee and rubber trees on the middle portion of the station reservation and about 1 acre of coffee on the upper Tantalus ridge.

About 200 cuttings of vanilla were placed in a grove of Keawe. The plants have rooted nicely and may be expected to begin to bear in a year or more.

The Bluefields bananas that were imported by the station several years ago have been extensively propagated and about 1,000 suckers have been distributed among some fifty growers, and already very favorable reports concerning them have been received. As these bananas are now quite widely distributed, the station will not continue their propagation on as large a scale as formerly.

In January, 1906, 265 pounds of grass and other forage plant seed, collected on the ranges of southern Arizona, New Mexico, and elsewhere, was distributed to about fifty members of the Hawaiian Stock Breeders' Association. The collection included seed of white grama, gray weed, Japan fodder, winter orchard rye, side-oats grama, Spanish sulla, sainfoin, *Paspalum dilitatum* from Australia, and other varieties. Many of these grasses and forage plants are now well established on some of the island ranches, and it is believed that they will aid materially in restocking the ranges that have been overpastured.

A collection of limus, or edible seaweeds, was made in the shallow waters of the islands, and chemical studies and cooking experiments performed with them in order to determine the extent to which it might be profitable to revive a former Hawaiian industry in these plants. The seaweeds which supply the agar-agar and Irish moss of commerce are fairly abundant in the island waters about Hawaii, and there appears to be no insurmountable difficulty against building up quite a local industry in the preparation of these marine food plants.

COOPERATIVE WORK.

GRAPES.

The growing of grapes has been followed to a limited extent in Hawaii for many years, but has never become what might be called an industry in any sense. On the island of Maui a rather extensive coöperative experiment in growing wine grapes has been begun. One hundred and seventy-seven varieties of wine grapes were planted by the station horticulturist in March, 1906, and the further expense of the investigation is to be paid by the owners of the vineyard. The growing of table grapes is carried on to a limited extent by some of the Portuguese settlers and others (Pl. I, fig. 1), and with the anticipated increase of immigrants from Spain, Portugal, and the Azores it is believed that grape growing and wine making will become profitable industries.

RUBBER.

An important experiment in rubber production has been begun at Nahiku, Maui, in cooperation with a rubber company. The growing of rubber-producing trees in Hawaii is not of recent introduction, as isolated trees of a number of the best known varieties are to be found here and there and in some places small groves exist that have suffered more or less from neglect. A number of companies have been recently organized for producing rubber, and the one cooperating with the station has set apart 1½ acres of land planted to rubber trees for experiments with fertilizers, variety tests, methods of tapping, preparation of rubber for market, etc. The difficulty of obtaining seeds of rubber trees and the low vitality of some shipments will make the extensive development of this industry rather slow. The station is cooperating with the Territorial board of agriculture and forestry in securing seed of the better known varieties. The question of growing the trees does not need demonstration, but the economic production of rubber remains to be investigated. One or two small groves of Ceara rubber trees large enough for tapping purposes have been located, and arrangements have been made to conduct careful experiments to determine the yield of these trees (Pl. I, fig. 2). These experiments will be extended as opportunity offers.

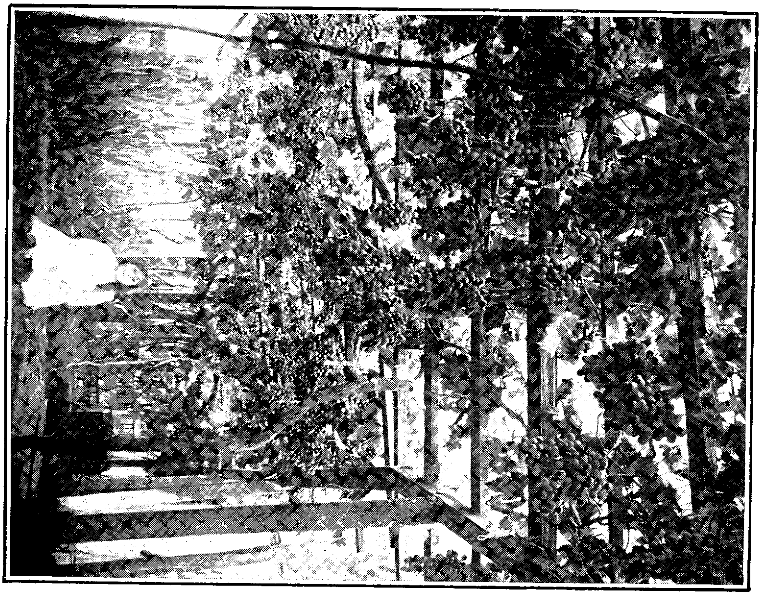

FIG. 1.—GRAPES GROWING AT HONOLULU.

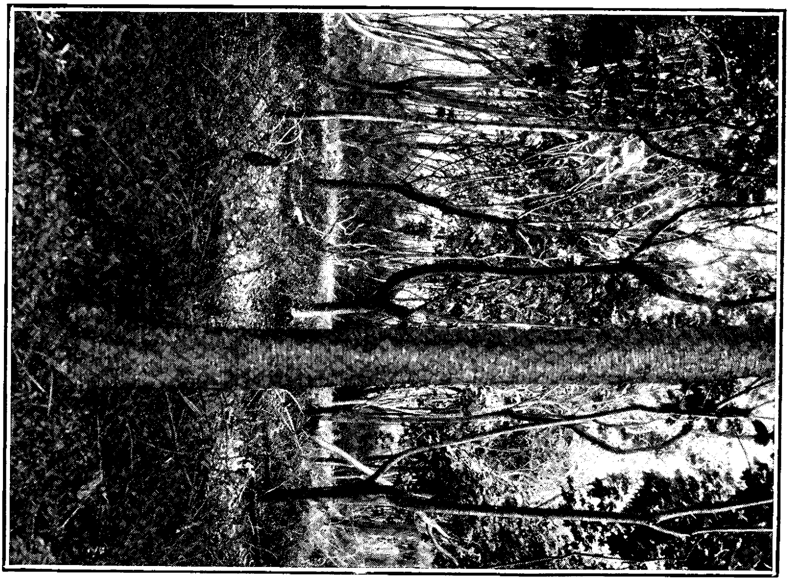

FIG. 2.—GROVE OF SEVEN-YEAR-OLD CEARA RUBBER TREES.

TOBACCO.

The tobacco investigations carried on by the station are in cooperation with the Territorial board of agriculture and forestry, assisted by contributions from a number of individuals. The experiments with tobacco were begun in 1904, and in October, 1905, the first samples of Hawaiian-grown tobacco were submitted to expert judges for examination. Samples were sent to all parts of the mainland, and about 150 pounds were made up into cigars for distribution in Hawaii. The experts who examined the tobacco leaf are of the opinion that it is of good burn and flavor and that the elasticity, firmness, and general texture place all of the samples in the wrapper class.

The quality of the leaf is due to the soil and climate. The tobacco belt of Hamakua is coincident with that portion of the mountain slopes where the clouds gather almost every day in the year. The mornings are usually clear, with full sunshine, but before the heat of midday clouds drift in from the ocean and rest over the lower slopes, disappearing again toward evening. In effect the Hamakua tobacco is shade-grown, not by virtue of being planted under cloth tenting, but because of Mauna Kea's fog bank. It is a tenting that is rolled over the fields by nature's hand.

In February, 1906, a crop was planted on lot 17 Paauilo Homestead, this tract of 110 acres having been set aside by the Territorial commissioner of public lands for the use of the station for a period of three years. Five acres of abandoned coffee were cleared, part of the land plowed, and the balance merely hoed. Seed beds were started, and as rapidly as plants could be obtained these were transferred to the fields. The field work was begun so late that the cost was much greater than it should have been. Lumber was purchased, and a curing barn large enough to care for the crop of 5 acres was erected; but even with all the expedition the house was not ready in time to care for the first of the crop, and, as in previous years, a part was lost through its becoming overripe. The tobacco work for 1906 cost about $6,000, half of which was subscribed by three citizens of Hawaii.

The completion of the fiscal year 1906 thus saw a substantial beginning toward a trial of tobacco on a field scale. The tobaccos growing at that date were Sumatra, Turkish, Cuban, and various seed-leaf strains from Connecticut, Pennsylvania, and other tobacco-producing States. While the crop is not yet finished, the fermentation process not being completed, it has been pronounced by many experts to whom samples of the tobacco were submitted as of as good quality as any tobacco produced anywhere in the world. A German manufacturer who examined samples of our 1905 tobacco stated that in his opinion the Hamakua leaf is unexcelled in burning qualities, being superior in that respect to most mainland varieties, and that the mild flavor places it on an equality with the best Brazilian and some Cuban sorts.

A Philadelphia leaf buyer stated that the samples submitted to him were worth as filler 20 cents per pound unsorted. Small samples of wrapper were variously priced according to style and color at from 50 cents per pound up to $4.50 per pound.

The results of the 1906 crop are such that it will hardly be necessary to attempt any further demonstration on a field scale, but there are many points connected with the curing, fermenting, and sorting, and with the treatment of the plants in the field, on which the station could do good work, provided arrangements can be made to carry on such work in cooperation with growers. It has been demonstrated absolutely that tobacco of good burn, texture, flavor, and color can be produced on a commercial scale and probably at a very large profit in certain districts in Hawaii.

COFFEE.

In January, 1906, the special agent in charge of the station was requested by some of the coffee growers on the island of Hawaii to visit Washington, D. C., to work on their behalf in favor of the coffee industry, which is much in need of relief.

The coffee industry is one especially adapted to the development of a stable population of small landowners. The coffee belt lies at an elevation of from 1,000 to 3,000 feet, the most salubrious location in the islands, a region of comfortable temperatures the year around. Coffee does not require a large outlay of capital in its cultivation, and it is a crop which can be prepared for market without expensive machinery. When once prepared, it does not deteriorate, but, on the contrary, constantly improves with age, so that the producer is not subject to the great losses which frequently happen to those engaged in the production of perishable crops. There are no difficulties about growing coffee in Hawaii. The trees are remarkably free from disease, the yields are high, and returns sure. Coffee is a cash crop which can be drawn against as soon as a single bag is started on its ocean journey to the market. The chief cause of failure as regards coffee growing in Hawaii is due to economic conditions. The best grades of Hawaiian coffees have always been in demand, and these grades sell themselves. The low grades, however, can not be produced in competition with Brazil and similar countries, and practically every small producer engaged in coffee growing in Hawaii has been forced out of business (Pl. II, fig. 1). A few of the larger growers who remained have managed to continue only through the exercise of the most vigilant care and economy, and have held on more because they had faith in the future than on account of actual profits returned upon their investment.

Another factor affecting the coffee situation is that the character of the coffee trade as a whole is changing. The bulk of the coffee now

PLATE II.

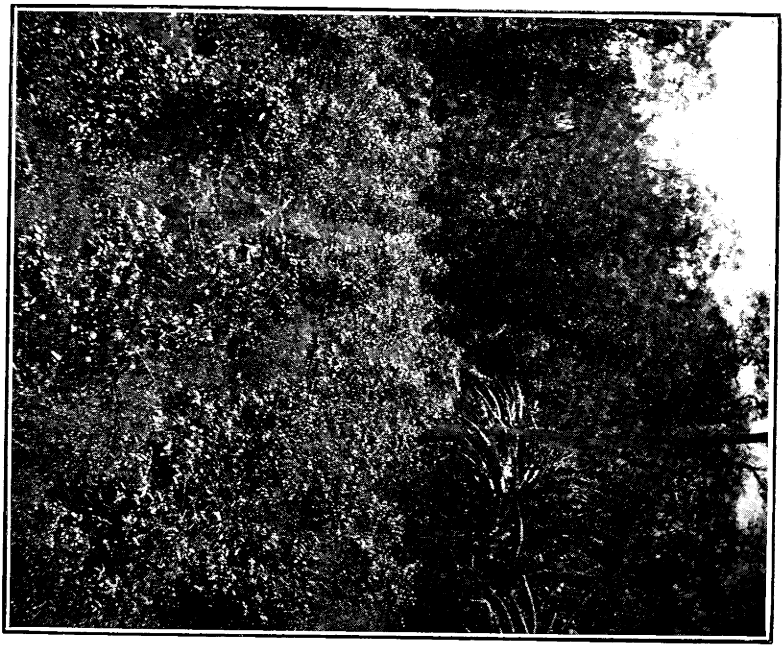

FIG. 1.—ABANDONED COFFEE, OLAA.

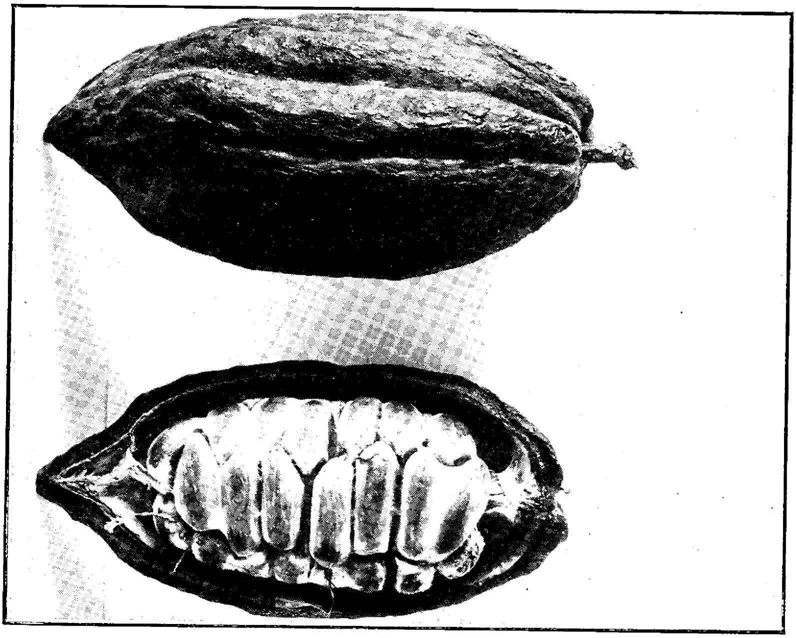

FIG. 2.—THE SAMOAN CACAO.

purchased by the consumer has been roasted or roasted and ground. This practice lends itself to the substitution of low grades for high grades, especially when coffee already ground is placed on the market. It is believed that a considerable quantity of coffee that under the old conditions would be unsalable is worked over and mixed with good grades in the so-called "package" coffees.

RICE.

Rice was formerly one of the important Hawaiian crops, but the industry has been in a bad way on account of increasing competition with rice from Japan, Louisiana, and Texas, and to some extent through the deterioration of the local product as well as the expensive methods of cultivation. Through the generous cooperation of several prominent estates a series of experiments was begun by the Hawaii station to determine what improvements in methods of cultivation, harvesting, fertilization, milling, breeding, and selection could be introduced to bring about the rehabilitation of the industry. Mr. F. G. Krauss, formerly in charge of the agricultural work of the Kamehameha schools, was secured to have this work in charge, and the lines of investigation planned embrace rice culture, breeding, and fertilization, and rotation of crops. Through the cooperation of the Bureau of Plant Industry of the Department of Agriculture 150 varieties of rice were obtained from different parts of the world for trial in comparison with the local varieties. These experiments have not progressed far enough to report definitely upon them, but it is believed that by improved methods of culture, the introduction of modern machinery, and the improvement of varieties it would be possible to restore rice growing to its former important position.

CACAO AND BANANAS.

The cooperative experiments with these two crops on the grounds of the Hilo Boarding School have been continued. Important collections of varieties of these plants, especially cacao (Pl. II, fig. 2), are desirable, and will be extended as rapidly as possible. The growth of the cacao during the past year was decidedly unfavorable, the poor results being attributed in a large degree to an unusual drought in a region which is generally considered as having exceedingly heavy rainfall. The bananas planted for shade have grown well and some varieties have fruited, so that the experiments can not be considered a failure, even though the results with cacao have not been very flattering.

CHEMICAL INVESTIGATIONS.

The work of the chemist has been divided between ordinary routine work and research investigations. Prominent in the routine work has been the completion of the analyses of some of the more important Hawaiian fodders and feeding stuffs, the results of the investigation having been published in Bulletin 13 of the station. The most important result of this work was the establishment of the fact that many Hawaiian-grown fodders contain insufficient lime for the needs of live stock. Considerable interest on the part of stockmen has been shown in this work, and the feeding of bone meal with the other rations or mixed with salt is being practiced by some of them. Studies were made of a number of samples of soils to determine their adaptability for tobacco growing. Another line of work that seemed to offer opportunities for development was the utilization of various by-products as sources of alcohol. Studies were made of a number of these, among them the waste from pineapple canneries, bananas, ti root, etc., to determine their value for fermentation and distillation.

The research work was mainly along the same lines of investigation as those described in previous reports, namely, a study of the nitrogenous compounds in Hawaiian soils. These investigations have been carried forward to such an extent that the chemist has prepared a first report on them, which is given elsewhere (see p. 37). Some studies were begun on the manganese content of some of the soils of Hawaii, samples from Wahiawa, Oahu, containing as much as 10 per cent of that substance. A portion of the chemist's time was devoted to making dietary studies to determine the nutritive value of some of the foods used in Hawaii.

ENTOMOLOGICAL INVESTIGATIONS.

The station entomologist has devoted considerable attention to the preparation of a card catalogue of the literature relating to economic entomology of Hawaii and in extending the collection of insects of economic importance. The investigations carried on by him have been along lines of the control of insect depredations, of silk culture, beekeeping, and mosquito control. In cooperation with the station chemist studies were made of Hawaiian honeys to determine the sources from which they were gathered. Two new races of bees have been introduced during the year, and one gives promise of being better suited to Hawaiian conditions than the Italian bees now reared. The enemies and diseases of bees are being studied, with a view to including these topics in a contemplated report on the bee industry in Hawaii.

The silk work was along very much the same line as that described last year. Through the cooperation of the Bureau of Entomology of the U. S. Department of Agriculture, a quantity of eggs of the Oro race of silkworms was obtained and bred for comparison with the races previously reared. A detailed report of these investigations will be found elsewhere (p. 19).

The entomologist continues to act with the local committee in attempting to control the spread of mosquitoes about Honolulu. During the past year the most important work along this line was the successful introduction of surface-feeding minnows to feed on the mosquito larvæ in fish ponds, taro fields, rice fields, and other places where draining and spraying are impracticable. A full report on their introduction is given on another page (p. 25).

HORTICULTURAL INVESTIGATIONS.

The horticulturist, in addition to caring for the nurseries and orchards and extending the collections as rapidly as possible, is devoting especial attention to the marketing of tropical fruits. Trial shipments of avocados were made to New York City in 1905 and other lots were successfully sent in cold storage on some of the army transports to Guam and Manila. Following the successes with these preliminary shipments, in June, 1906, preparations were made for an experiment with larger lots of pineapples, avocados, papayas, and bananas, and in August a shipment of about six tons of these fruits was made to San Francisco, accompanied by the horticulturist. The fruits were packed in various ways to determine the best method of commercial handling, and observations of the fruit were made between Honolulu and San Francisco to learn some of the transportation problems of the ocean voyage. A number of cities on the Pacific coast were visited and the fruits exploited. The tests were highly satisfactory, and it is believed that enlarged markets for these fruits are assured whenever regular supplies can be secured.

In this connection one of the first matters taken up in 1906 was that of a fruit-marketing association. Such an organization would enable the producer to secure more favorable selling prices, and it would also result in more regular supplies of fruit of uniform character. Considerable correspondence was carried on by the horticulturist with various fruit growers and shippers in the Hawaiian Islands with a view to the formation of such an association. While no definite results have as yet been obtained, it is believed that such an organization will shortly be formed.

PUBLICATIONS.

During the year the station issued the following publications:

Bulletin No. 11. The Black Wattle in Hawaii, by Jared G. Smith.

Bulletin No. 12. The Mango in Hawaii, by J. E. Higgins.

Bulletin No. 13. The composition of some Hawaiian Feeding Stuffs, by E. C. Shorey.

Press Bulletin No. 15. Lime an Essential Factor in Forage, by E. C. Shorey.

Press Bulletin No. 16. The Avocado Mealy-Bug, by D. L. Van Dine. This is an enlarged and revised edition of Press Bulletin No. 8, the supply of which had become exhausted.

In addition to these publications, the special agent in charge and various members of the staff have contributed articles along agricultural lines to the Hawaiian Forester and Agriculturist and the local press.

REPORT OF THE ENTOMOLOGIST.

By D. L. Van Dine.

As the entomological investigations of the station have progressed, certain lines have developed sufficiently to make a classification of the work possible. The more important lines are the injurious insects of the islands and their control; mosquitoes and their control; silk culture, and beekeeping. Along with these definite lines of work there is an amount of routine and miscellaneous work not easily classified. As heretofore, the entomologist has worked without an assistant, and would urge such an appointment as needful to the increasing demands made upon the station staff in general and the consequent development of this phase of the station work. A good equipment and working library are now at hand.

The correspondence is of a more satisfactory nature than during the first years of the station's existence. More cooperation is manifested in the problem of determining the sources of insect injury and the question of their suppression. This is due to a better understanding of the principles of insect control and the use of insecticides.

The work on the collection and records has been somewhat neglected during the past year and necessarily so in the face of more pressing duties. A permanent start has been made, however, and both phases of the work will receive more consideration when additional assistance is forthcoming. The collection of Coccidæ is especially complete, mounted in Riker mounts in connection with their food plants for exhibition purposes.

Aside from the annual report for the last fiscal year, the entomologist has published press bulletins Nos. 14 and 16 of the regular station series on Fuller's rose beetle (*Aramigus fulleri*) and the avocado mealy-bug (*Pseudococcus nipæ*), respectively. Many articles have also been supplied the local press and The Hawaiian Forester and Agriculturist on subjects relating to the entomological work of the station.

The field work has, as formerly, occupied a large amount of time. It is imperative that an intimate knowledge of the conditions in the varying localities of the islands be obtained at first hand to satisfactorily solve the problems that present themselves in carrying out the various projects. Many trips were made about the island of Oahu and one to the Hilo district, island of Hawaii, in the distribution of the top-minnows, which are discussed under the subject of mosquito control. One trip was made to the Nahiku district, island of Maui, to make an entomological inspection of the newly established rubber plantations in that locality. One trip was made to the Kohala district, island of Hawaii, in a survey of the insects injurious to field crops other than sugar cane on the homestead lands of that district.

Repeated trips were made to the outlying districts of Honolulu in the study of beekeeping and the distribution and life cycle and habits of the mango weevil (*Cryptorhynchus mangiferæ*).

The entomologist acknowledges gratefully many courtesies from colleagues throughout the country and abroad and would mention the help received from Dr. L. O. Howard and the other experts of the Bureau of Entomology in determinations of specimens and investigations in silk culture and beekeeping.

SILK CULTURE.

REPORT OF COCOONS GROWN IN 1905 EXPERIMENT.

Under date of November 6, 1905, the following letter was received from the Bureau of Entomology, United States Department of Agriculture:

Dear Mr. Van Dine: In the temporary absence of Dr. L. O. Howard, I have to answer your letter of the 8th ultimo, which was received some time since, but has been held pending the arrival of the cocoons. These cocoons have just come to hand and are in excellent condition, and are well worthy of being graded as first-class. They are not, however, as firm as some specimens of Sferici cocoons received this season, yet are very superior to many others which have come to our notice. I think this lack of firmness is not due to lack of care, but to the moisture-laden air of the islands; or, in other words, I think that the race is not well suited to your locality. Perhaps a Japanese race or a cross with a Japanese race would make a better cocoon. No reeling has yet been done to your cocoons, but I feel sure that a large percentage of floss or loose waste silk will result. We will advise you in this regard later.

So far as the price of cocoons goes, you must be aware that there is practically no market for them in the United States. We are trying to stimulate an artificial market by buying cocoons at from 90 cents to $1.15 per dried pound. This is slightly above the current European price. We also pay transportation under certain conditions. Our ability to purchase cocoons depends entirely upon Congressional action and therefore it is impossible to say how long we can continue to buy cocoons. I inclose herewith for your information a circular on silk culture which we are sending out very extensively, which will give you some idea of the lines we are following.

Our supply of silkworm eggs for next season's distribution has not yet been received from abroad, so we can not send you an ounce of eggs at this time. However, we will send you an ounce in the spring, just as soon as it is safe to do so.

We will reel your cocoons and return the raw silk to you, but I regret we will be unable to weave any of it into cloth, as we have no machinery for this latter process.

Very respectfully,

C. L. Marlatt,
Acting Chief of Bureau.

Mr. D. L. Van Dine,
Experiment Station, U. S. Department Agriculture, Honolulu, Hawaii.

Regarding the percentage of floss or waste silk resulting from the reeling mentioned in the above letter, Doctor Howard advised the writer under date of December 11, 1905, that "contrary to expectations, some of the results have shown a truly remarkable silk in many ways, especially in economy of reeling."

The detailed report on the cocoons was received under date of December 23, 1905, and is as follows:

Dear Mr. Van Dine: I am returning you this day, by accompanying mail, the silk which has been reeled from your cocoons, less one skein, which was used in making tests. Please find inclosed a copy of a letter from Mr. James Chittick, secretary of the Clifton Silk Mills, Weehawken, N. J., relative to the qualities he found in your silk.

So far as your part is concerned the actual raising of the cocoons was certainly successful and you are to be congratulated with the splendid showing which they make. The strength and elasticity of the fiber and the very economical reeling results could not be bettered. Generally speaking it requires 4 pounds of dried cocoons to produce one pound of raw silk in the reeling; your cocoons produced 1 pound of silk to about 3 pounds of cocoons, which is equal to the most economical results obtained in experienced silk-producing countries. The weak places in the thread, causing numerous breaks, was entirely the fault of our reelers. Hairiness is due to the nature of the cocoon employed. We were well aware of this feature before sending you the eggs, but as the Sferici is a particularly hardy race and one safe to put into the hands of our inexperienced people, we have laid aside commercial qualities to some extent until a higher degree of proficiency should be attained by the producer and for this reason have distributed more eggs of the Sferici than of any other race. Commercially there is no comparison of this race with China and Japan silk. This feature is strongly brought out in the next phase—gumminess. Ordinarily the silk from your type of cocoon should have given a loss of 24 per cent in weight in the boiling-off process, due to the solubility of the gum. Actual tests showed a loss of 28 per cent, or 4 per cent in excess of the ordinary. This is no doubt due in great measure, if not entirely, to atmospheric conditions, and seems to show that the Sferici race, as stated in a previous letter, is not entirely suited to Hawaii. Japan silk loses 18 per cent and China silk 19 per cent in the boiling off.

In the eggs to be sent you in the spring I will try and select those of a race which seems better suited to Hawaii, though in this matter we must be guided mainly by experiment. Judging from results obtained in Hawaii between the years 1837 and 1842, by using a cross between the Canton white and yellow and the so-called American race, I am inclined to believe that by all means a cross race should now be used and that the Canton white or yellow be employed as a basis.

Yours, very truly,
L. O. Howard,
Chief of Bureau.

Mr. D. L. Van Dine,
Experiment Station, U. S. Department of Agriculture, Honolulu, Hawaii.

REPORT OF CLIFTON SILK MILLS.

The Clifton Silk Mills, Post-Office, Weehawken, N. J.,
Town of Union, N. J., December 16, 1905.

Dr. L. O. Howard,
Bureau of Entomology, U. S. Department of Agriculture, Washington, D. C.

Dear Doctor Howard: I beg to report on the Hawaiian silk as follows:

The silk seems generally to have good strength and elasticity. It seems in places to be rather irregularly reeled, the result being that in the winding it breaks much oftener than it should.

This skein broke seventeen times in the winding, whereas silks that we are regularly handling would not break more than three times at the most. Still, it is only fair to say that as this skein had been opened and examined by us before putting on the winding, it might have fared a little better in this respect had it gone directly on the machine. There were, however, scattered through it, weak places.

The size of the silk we make to be about 14 deniers. To get a proper judgment we threw this into two skeins of organzine and boiled off one of the skeins. The boiled-off skein weighed 786 grains and after boiling off weighed 565 grains, a loss of over 28 per cent. One per cent of this might be accounted for by soap and oil, and possibly there may have been some atmospheric difference between the time it was weighed in the thrown state and in the time it was weighed in the boiled-off state.

As we are returning to you the skein of organzine not boiled off, you can make yourself exact determinations in this respect from the former.

We do not think that the soap and oil put in here will amount to more than 1 per cent, as previously stated.

On putting some of this boiled-off silk on the testing reel for examination (in which state you can form a sounder opinion than you can before boiling off), we find that it makes a very fair organzine, being quite regular, with a good deal of elasticity, and fairly brilliant.

The main criticism to be made of it is its hairiness, and this is due principally or entirely to the nature of the cocoons.

For comparison, we would say that it is very similar to an Ardeche classical silk. Ardeche ranks in about the second grade of Cevennes silk, and classical, as you know, is the second classification. This hairiness is common to all Cevennes silks.

By getting European quotation on the grade above referred to you will therefore be able to arrive at a fair idea of its commercial value.

The Piedmont, China, and Japan silks are, of course, not so hairy, and this hairiness would make this silk unsuitable for some purposes.

I would suggest that you would find it of interest to wind a little, both of the boiled-off and the unboiled-off, and by then winding them onto a testing reel you will be able to get an excellent idea of the points above referred to.

Referring to what you say in your letter of November 16, I would state that a return of 1 pound of silk for 3 pounds of cocoons is a first-class return.

If there are any other points that you would like to be advised about in connection with this, I shall be pleased to take them up with you.

Very sincerely, yours, James Chittick.

Regarding a market for dried cocoons, the following is quoted from the circular referred to in Mr. Marlatt's letter of November 6, 1905:

It is hoped that before long private enterprise will take up the matter of erecting silk-reeling plants, and thus create a permanent market for the cocoons. In the meantime, so long as Congress appropriates for the purpose, we will buy cocoons at from 90 cents to $1.15 per pound, at point of shipment, *for thoroughly dried cocoons.* Shipments weighing less than 4 pounds may be sent by mail, and for this purpose a Government frank will be provided on application, thus putting the shipper to no expense for transportation charges. Small lots of cocoons weighing something over 4 pounds may be divided into several shipments, each package being under a separate frank. Absolutely no cocoons must be sent by mail unless choked and dried. This is important, as otherwise there is liability of injury to other mail matter en route. Shipping by express has been found too expensive, and its use is now discouraged. Large shipments should all go by freight, *charges collect.* In no case where transportation is *prepaid* can the charges be refunded by this Bureau, neither will shipments by express be credited with expressage under any condition. We are operating a reeling plant at this office in order to convert cocoons into marketable raw silk.

From the above it is seen that persons producing even a small amount of cocoons can dispose of them at a price above the current European price *at point of shipment.* Anyone interested in the growing of silkworms should apply to the Secretary of Agriculture, Washington, D. C., for the Circular of Information in Regard to the Work in Silk Culture, and for Farmers' Bulletin No. 165, Culture of the Silkworm.

RESULTS OF EXPERIMENTS IN 1906.

On March 28, 1906, 1 ounce of eggs of the Oro race, a Chinese variety of silkworms, was received from the Bureau of Entomology, per the steamship *Alameda.* These eggs were forwarded from Washington, D. C., to Mr. E. M. Ehrhorn, deputy State horticultural commissioner, San Francisco, by mail on March 7, 1906. They were placed by Mr. Ehrhorn in cold storage aboard the steamer on March 15, 1906. On arrival in Honolulu the eggs were taken directly from cold storage aboard the steamer to the ice house of a meat company (temperature 42° F.). They were not exposed at once to hatch, since the mulberry trees had not at that time started to put out their new growth of leaves. This was unusual, but explained by the fact that there had been a drought of several months in length that had forced the trees into a semidormant state. On April 2 the eggs were inspected and the box found to contain many dead newly hatched worms. The writer could account for this state of affairs only upon the presumption that the development must have taken place en route from Washington to San Francisco, since the temperature on the steamer did not at any time exceed 40° F. The eggs were removed from the ice house at once and placed in an ice box at a temperature ranging between 50° and 60°. April 3 the eggs were exposed in the building used for the breeding purposes at a temperature ranging from 70° to 86° and the hatching began at once. Because of the shortage of the food supply only one-half of the eggs were retained for the experiment and the remaining half distributed to various parties who had from time to time requested eggs for breeding from an interest in the natural-history side. The hatching was very slow, and at the end of the fifth day, or on the morning of April 8, the remaining unhatched eggs, consisting of fully two-thirds of the half ounce, were thrown away. Despite the slow hatching the development was very regular, as shown by the following table. The date of hatching implies the worms hatched during twenty-four hours; for example, the hatching recorded on April 3 consists of the worms developing between 7 a. m. April 3 and 7 a. m. April 4.

Table showing hatching and development.

Date of hatching.	Molting periods.				Date of spinning.	Total life period (days).
	First.	Second.	Third.	Fourth.		
April 3	Apr. 10	Apr. 14	Apr. 19	Apr. 26	May 3	30
April 4	Apr. 11	Apr. 15	Apr. 20	Apr. 27	May 5	31
April 5	Apr. 12	Apr. 16	Apr. 22	Apr. 28	May 6	31
April 6	Apr. 13	Apr. 17	Apr. 23	Apr. 29	May 7	31
April 7	Apr. 14	Apr. 18	Apr. 24	May 1	May 8	31

The feeding table is incomplete, since at the beginning of the fourth age some of the worms had to be thrown away because of the shortage of the food supply; that is, less than one-sixth of an ounce of eggs were carried through to the cocoon stage. The amount of leaves fed is rather large, but it must be borne in mind that from the start the leaves were old and at every feeding there remained quite an amount uneaten to be thrown away.

Time of feeding and food consumed by silkworms from less than one-sixth ounce of eggs.

Date.	Times fed per day.	Amount consumed in 24 hours.		Date.	Times fed per day.	Amount consumed in 24 hours.		Date.	Times fed per day.	Amount consumed in 24 hours.	
		Lbs.	*Oz.*			*Lbs.*	*Oz.*			*Lbs.*	*Oz.*
April 3	7	0	½	April 16	7	2	0	April 29	6	16	0
April 4	7	0	2½	April 17	7	2	8	April 30	6	16	0
April 5	7	0	7	April 18	7	3	1	May 1	5	20	0
April 6	7	0	8¾	April 19	6	3	0	May 2	5	22	0
April 7	7	0	12	April 20	6	4	0	May 3	5	25	0
April 8	7	0	12	April 21	6	5	0	May 4	5	31	0
April 9	7	1	0	April 22	6	6	0	May 5	5	35	0
April 10	7	1	0	April 23	6	6	0	May 6	5	20	0
April 11	7	1	0	April 24	6	7	6	May 7	5	18	0
April 12	7	1	8	April 25	6	10	0	May 8	5	10	0
April 13	7	1	8	April 26	6	10	0	May 9	5	5	0
April 14	7	1	8	April 27	6	13	0				
April 15	7	2	0	April 28	6	12	0	Total	....	314	1¾

The temperature ranged from 86° maximum to 65° minimum, with a mean maximum of 82.32° and a mean minimum of 67.62°; also during the above time the sky averaged part cloudy, with twelve clear days.

REPORT ON ORO COCOONS.

Under date of June 26, 1906, the following report was received from the Bureau of Entomology, United States Department of Agriculture:

> Dear Mr. Van Dine: Referring to my letter to you of the 22d instant, I beg to state that Mr. Gilliss reports as follows on your cocoons:
>
> It is thought that the Oro Chinese race as a basis for crossing with other races may produce a cocoon particularly adapted to Hawaii. While the cocoons sent by you are somewhat undersized, they are of a very good quality, indeed, and contain a fair amount of silk. Of course, owing to adverse circumstances under which your worms were raised, it is hardly possible to consider this rearing as a fair test. We find it almost impossible to furnish you with silkworm eggs in good condition, owing to the length of journey and varying temperatures to which the eggs are necessarily

subjected en route. It is thought that you should be able to obtain eggs in better condition by shipping directly from the sericulture establishments of Japan and China. We are glad to know that the eggs furnished by us have proved to be healthy. The hatching of a certain proportion of the larvæ en route is a matter we can not control, as the journey between Washington and San Francisco must be performed without the use of cold storage.

The photographs are very interesting to us. We note that you use swinging shelves, presumably to guard against mice, ants, or other vermin, and we consider this an excellent idea. I might suggest, however, that, instead of the close-bottomed box used, it might be better to use something which would tend to ventilate the bed whereon the worms are being reared. Especially is this true during a moist, warm spell of weather, when the leaves tend to ferment and mold. Much attention has been paid by us to this point during the last season.

While we can not supply you with the number of mulberry trees which you would require in the carrying on of your work, we may be able next fall to send you several thousand seedlings of the best white mulberry if you wish.

Tests will be made within a short time regarding the length and strength of the fiber of your cocoons, and we will then take pleasure in advising you of results.

Yours, very truly,

F. H. Chittenden,
Acting Chief of Bureau.

Mr. D. L. Van Dine,
Hawaii Experiment Station, Honolulu, Hawaii.

BEEKEEPING.

The investigations relating to apiculture in Hawaii have been continued along the lines detailed in the project of this station on the subject. Two queens representing the Cyprio-Carniolan and Cyprio-Caucasian crosses, respectively, were received from the Bureau of Entomology and introduced in the apiary of a company on the island of Oahu. While a definite opinion can not be given at this time on the value of these bees as compared with the bees already established here, it can be said that they are at least as vigorous and industrious as our best Italians. Further introductions of desirable races and crosses are planned in cooperation with the Office of Apiculture, Bureau of Entomology.

Hawaii is particularly fortunate in that neither European nor American foul brood—serious diseases in most beekeeping sections of other countries—have not as yet gained a foothold in our apiaries. Suitable legislative action will be recommended to the next Territorial legislature to prevent, if possible, the introduction of these diseases or to deal with them should they unfortunately become established. As to enemies, none of serious consequence have been observed. Both the diseases and the enemies of bees will be carefully worked out and considered in a forthcoming bulletin on the industry.

The source and chemical characteristics of Hawaiian honeys have been little understood up to this time. This phase of the project has and will continue for some time to take up the greater part of the time devoted to this part of the entomological investigations of the station. Up to the close of this fiscal year thirty-three samples of honey have been collected of which the source has been determined. These samples have been handed to the chemist of the station for analysis. The writer estimates that fully twice this number must be worked out before the completion of the survey of the sources of Hawaiian honey. In this connection, the question of introducing desirable bee plants for pasturage will receive attention.

The writer has been successful in forming a temporary organization of the beekeepers for the purpose of effecting a permanent association whose object will be the development of apiculture in Hawaii.

MOSQUITO CONTROL WORK.

Work along the line of this project has been confined almost entirely to the breeding and distribution of the top-minnows introduced from Texas during the early part of this fiscal year. To briefly summarize: The question of introducing special mosquito-eating fish to feed on the larvæ of mosquitoes in such collections of water as taro patches, rice fields, irrigation ditches, reservoirs, seacoast swamps, etc., was taken up with Dr. David Starr Jordan by the writer in the early part of 1903. Doctor Jordan recommended the top-minnows found in the Mississippi Valley, Florida, the Gulf States, and Mexico. The cost of the undertaking prevented anything from being done until a visit of Doctor Jordan to the islands made a personal interview on the subject possible. Doctor Jordan offered to send an expert from Stanford University to collect the fish and import them, providing the Territory would pay the expenses of the undertaking. During the session of the legislature in 1904 the matter was presented to the governor and received his indorsement, with the result that an item of $1,500 for "Expenses, importation of fish for the destruction of mosquitoes," was appropriated. The legislature placed the item in the regular bill of expenses of the Territorial board of health, and accordingly that body had the disbursement of the money. Doctor Jordan selected Mr. Alvin Seale to undertake the work, and the writer procured the privilege of using a portion of a rice field on the country estate of Hon. S. M. Damon, at Moanalua for a breeding place, and therein prepared the breeding ponds to receive the fish.

The following report from Mr. Seale gives the method employed in collecting the fish and transporting them to the islands:

HONOLULU, HAWAII, *September 23, 1905.*

MR. D. L. VAN DINE,
Entomologist, U. S. Experiment Station, Honolulu, Hawaii.

DEAR SIR: In accordance with the following letter to yourself from Dr. David Starr Jordan I was chosen to attempt the introduction of "top-minnows," or "killifish," into the Hawaiian Islands, for the purpose of destroying the larvæ of mosquitoes:

LELAND STANFORD JUNIOR UNIVERSITY,
OFFICE OF THE PRESIDENT,
Stanford University, Cal., April 18, 1905.

Mr. D. L. VAN DINE,
United States Experiment Station, Honolulu, Hawaii.

DEAR SIR: The best place to collect the fishes which you want would doubtless be in Louisiana. It would probably take no longer time to bring them from there than from any other places nearer. Perhaps an equally good place would be Tampico, on the edge of Mexico. You understand that this would necessarily be an experiment. These little fishes feed freely on mosquitoes. Some live in brackish water, some in fresh water, and all of them are very hardy; but no one has ever tried to transplant any of them, and the whole thing might turn out, for some reason or other, to be a failure. Especially one would need to experiment on feeding the little fishes during their transportation. The genera which I would recommend are Mollienesia, Adinia, Gambusia, and Fundulus. Some of these are viviparous; others lay eggs. Whoever undertakes this should give a good deal of attention to the question of feeding the little fishes, and for this purpose, perhaps, a tank breeding mosquitoes would be as good as anything. The best time to undertake it would be about the 1st of June. I will select some one as soon as I hear from you.

Very truly, yours,
DAVID S. JORDAN.

On receipt of yours of July 11, 1905, with the advance of $500 of the Territorial appropriation covering the expenses of this undertaking, I started from Stanford University to the Southern United States. It was my intention to secure the top-minnows at or near New Orleans, but the rigid quarantine in operation in Louisiana prevented my carrying out this plan. Seabrook, near Galveston, Tex., was then selected as the next place most available. At Seabrook I found the family of top-minnows, Pœciliidæ, in large numbers. They were swarming in all the stagnant waters at sea level as well as in various ditches, ponds, and standing pools. Mosquitoes are very plentiful in and about Seabrook, but after a study of the situation I am convinced that their source is not the bodies of water containing these fish but rather temporary and artificial breeding places, such as closed pools, tubs, tin cans, and other refuse which are not accessible to these fish.

As per his letter to you, Doctor Jordan recommended the following genera: Mollienesia, Adinia, Gambusia, and Fundulus. These are all members of the single family Pœciliidæ, or top-minnows. I first made a careful examination of a number of the stomachs freshly taken from members of the above genera. The stomach contents was found to consist largely of larvæ of various insects, including those of mosquitoes, egg masses of mosquitoes, minute crustaceæ, and some vegetation. The results showed that Gambusia were the best insect feeders. Of 100 stomachs of this genus examined, all contained many insect larvæ and eggs, among which I noticed especially numerous egg masses of the mosquito. However, Mollienesia, Fundulus, and Gambusia differed slightly in regard to their capacity for the various insect larvæ, and the difference was probably due to the different food localities. The temperature of the water in and about Seabrook in which these fish were found ranged from 74 to 87°.

It now remained to determine under what conditions the fishes could be most successfully transported to Hawaii. Six ordinary 10-gallon milk cans were prepared by puncturing the covers with numerous holes and placing the cans in bran sacks, the intervening space being tightly packed with Spanish moss. This served to keep the water at an even temperature. Two hundred fish were placed in each can. The following morning so many were dead that it was evident the cans were overcrowded, and I reduced the number to 100.

Experiments were conducted as follows:

Can No. 1: Allowed to stand undisturbed. Water unchanged and unaerated. Temperature normal. The first morning 6 fish were dead. The second day 2 died. The third day the fish were perfectly lively and were taking food freely. The fifth day 5 died, and by the eighth 20 had died. The experiment was not carried further.

Can No. 2: Water changed once each day. Temperature normal (ranged from 74 to 78°). During the first three days there were 4 deaths. The eighth day 2 died. After this time there were no more deaths. Fish fed freely on mosquito larvæ and prepared fish food.

Can No. 3: Water changed twice each day. Temperature normal. Three deaths the first night. After this time there were no more deaths. Fish fed freely on mosquito larvæ and prepared fish food.

Can No. 4: Water changed every two days. Temperature normal. Five deaths the first three days, after which no fish died. Fish fed freely, keeping constantly at top of the water.

Can No. 5: Water slowly and very gradually reduced in temperature to 40°. Fish would not feed at the end of six days. During this time 18 had died. Experiment discontinued.

Can No. 6: Water reduced slowly to freezing point, then can packed in ice. At the end of six days all but 3 of the fish were dead. Experiment discontinued.

The above experiments demonstrated that the fish should be transported in water at the normal temperature and gave the necessary information in regard to the frequency of changing the water.

The three most abundant species, *Gambusia affinis*, *Fundulus grandis*, and *Mollienesia lattipinna*, were collected and approximately 75 placed in each can. On September 4, 1905, I left Seabrook, Tex., on the long journey to Honolulu. A 20-gallon tin tank was taken along as a supply reservoir.

The following routine work was observed during the entire trip: At 8 a. m. the fishes were fed sparingly on prepared fish food, finely ground liver, or hard boiled eggs; at 9.30 half the water in each can was siphoned off from the bottom, thus cleaning out the cans and removing all uneaten food and excrement, and an equal amount of fresh water added; at noon the cans were all aerated by means of a large bicycle pump, a sponge being tied over the end of the hose to separate the air into fine particles; at 4 p. m. 2 gallons of water was siphoned off from the bottom and 2 gallons of fresh water put in; just before retiring the cans were again aerated by means of the air pump.

At each place en route where the water was changed it was first tested by placing two fish in a bucket containing the new water at the proper temperature At El Paso, Tex., only, did the water kill the fish thus treated. After ten minutes the two fish were dead, probably due to the alkali the water contained. The water at Los Angeles was good, as also the San Francisco water, which was used from the latter place to Honolulu, an abundant supply being carried on the steamer. The water used from El Paso to Los Angeles was taken from the supply tank, filled at San Antonio, Tex.

Twelve fish died between Galveston and San Francisco, and only 15 between San Francisco and Honolulu. The fish were landed in Honolulu from the steamship *Alameda* on September 15, 1905, the trip from Texas occupying twelve days and 27 of the approximate 450 fish were lost.

The fish were in fine condition on arrival and, as prearranged by yourself, were placed in the breeding ponds prepared for them. The temperature of the water about Honolulu is almost identical with that where the fish were collected, and the appearance of the fish at this writing indicates that they should thrive on the islands. The fish should be confined in the present breeding ponds, where they can be prevented from going out to sea or falling prey to other fish until their increased numbers permit general distribution to other localities in the group.

Very truly, yours,

ALVIN SEALE,
Assistant, U. S. Fish Commission.

The fish were divided into four lots and planted in as many places on the island of Oahu. In three places they were given their freedom under conditions distinctly different, and in the fourth place they were confined, namely, in the breeding ponds at Moanalua. The multiplication of these fish has been very rapid. Many hundreds have been distributed from the breeding ponds to various localities under varying conditions for observational purposes. The conditions under which they best thrive and the places best suited for them have been determined as a guide for their establishment throughout the islands. It is only a question of a few years when the shallow waters of the group, embracing the larger number of the natural collections of water where mosquitoes breed, will be teeming with these hardy, effective enemies of the mosquito larvæ. One point in this connection must be strongly emphasized—that is, that relief in towns, cities, and closely settled communities is dependent upon direct, active measures of control, since, in the main, the source of mosquitoes infesting closely settled districts is artificial collections of water, such as tubs, tanks, cesspools, discarded tins and bottles, gutters, water traps, and small ponds and ditches of a temporary character, or any collection of water not accessible to these fish. Relief implies general organized inspection and remedial work.

As stated in the 1905 report of the entomologist, organized effort to rid the islands of mosquitoes has ceased. This was due to the failure of the last legislature to provide the necessary funds to carry out the plans promulgated by the citizens' mosquito committee of Honolulu. The Territorial board of health, relying on money from private sources, has carried on control work in Honolulu and other districts of the islands, notably Hilo, as actively as the money available for the purpose would permit.

A PARTIAL LIST OF THE INJURIOUS INSECTS OF HAWAII, PART 3.

(Continued from Office of Experiment Stations Bulletin No. 170, 1906.)

SUGAR CANE.

The sugar-cane aphis (*Aphis sacchari*). Observed by Koebele in the cane fields of the islands of Oahu, Maui, and Kauai in 1896. At times appears in destructive numbers in certain localities, but not generally so. The ladybird beetle (*Coccinella repanda*) is a very important enemy of this species. The writer is indebted to Mr. G. W. Kirkaldy for the determination of the sugar-cane aphis.

A longhorned grasshopper (*Xiphidium varipenne*). This species eats to some extent the leaves of cane, doing no serious damage. Mr. Otto Swezey has clearly pointed out during the year the remarkable fact that this species devours the sugar-cane leaf-hopper in sufficient numbers to consider the grasshopper of benefit in the cane fields. Injurious to the flowers of rice.

RICE.

Mole cricket (*Gryllotalpa africana*). Frequents wet places, feeding on the root system beneath the surface of the ground. Is injurious also to taro and sugar cane.

A longhorned grasshopper (*Xiphidium varipenne*). Feeds to slight extent on the margin of the leaves of rice, but the more serious damage to the crop is in gnawing through the glumes to obtain the pollen, on which it feeds extensively during the flowering season.

A shorthorned grasshopper (*Oxya velox*). Feeds to some extent on the leaves of rice.

The rice weevil (*Calandra oryzæ*). A very common pest of stored products generally in Hawaii. The species is reported to infest the grain in the field before harvesting. This insect is very destructive to stored corn in the Kula district, island of Maui. Occurs in various foodstuffs aside from rice, especially flour, meal, breakfast foods, etc.

The rust-red flour beetle (*Tribolium ferrugineum*). Infests flour, meal, and rice. Taken also during the year in large numbers from fish guano and bone meal fertilizers.

The cadelle (*Tenebroides mauritanicus*). Taken in large numbers last year from bone meal and fish guano fertilizers. Reported as infesting stored rice.

MULBERRY.

The following scale insects infest the mulberry in Hawaii: *Pseudococcus nipæ*, *Pseudococcus filamentosus*, and *Saissetia* sp.

CEARA RUBBER.

A scale insect (*Saissetia nigra*) and a mealy bug (*Pseudococcus* sp.) were collected from Ceara rubber trees on the island of Kauai.

CITRUS TREES.

The orange aphis (*Myzus citricidus*). Very abundant and especially destructive to young growth. The species was recently described as new by Mr. G. W. Kirkaldy.

SCALE INSECTS, COCCIDÆ:

Chrysomphalus aonidum, collected during the year from orange. Found also on Allamanda and palms (*Pritchardia* spp.).

Pulvinaria psidii, on lime.

Pseudococcus filamentosus, at times very abundant. Especially injurious to young growth. The ladybird beetle (*Cryptolæmus montrouzieri*) is an important enemy of this scale.

Coccus viridis. Specimens of this scale were received from Mr. Jacob Kotinsky, collected from the "Giant lemon" at Honaunau, Kona district, island of Hawaii.

MANGO.

An undetermined lepidopterous larva was observed during the year destructive to the flowers of the mango and injuring partly developed fruit by feeding on the epidermis of mangoes in close contact in the cluster, between which the insect was hidden.

SCALE INSECTS, COCCIDÆ.

The mango scale (*Coccus mangiferæ*).

The Florida red-scale (*Chrysomphalus aonidum*).

Coccus longulus.

BANANA.

The scale insect (*Saissetia nigra*) was collected from the fruit and leaves of the banana during the year.

GRAPE.

The Japanese beetle (*Adoretus umbrosus tenuimaculatus*).

Fuller's rose beetle (*Aramigus fulleri*).

Lepidopterous larva (undetermined) observed by Mr. Jared G. Smith at Makawao, island of Maui, feeding on the stems of undeveloped fruit, causing the same to drop from the cluster.

SCALE INSECTS, COCCIDÆ.

The avocado mealy-bug (*Pseudococcus nipæ*).

Pseudococcus filamentosus.

MISCELLANEOUS.

The bean weevil (*Bruchus obtectus*) was taken from the seed pods of Klu (*Acacia farnesiana*).

The scale *Phenacaspis eugeniæ* is very common on oleander.

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[This list is supplemental to the bibliography of Hawaiian entomology in the Report of the Entomologist for 1905 (Office of Experiment Stations Bul. 170). In the latter the references in the station library are marked with an asterisk (*).]

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REPORT OF THE HORTICULTURIST.

By J. E. Higgins.

CITRUS FRUITS.

The quality of the imported citrus fruits is in striking contrast with the excellency of those grown here and which may be picked from the trees in some part of the islands almost every day in the year. It is without exaggeration to say that by multiplying some of the Hawaiian seedling oranges the season could be extended to include almost the whole year in most localities. Lemons in several varieties, limes unsurpassed anywhere, and seedling pomelos that compare favorably in flavor with budded fruit are to be found in the gardens of Honolulu and other parts of Hawaii. To assist and encourage the further cultivation of these fruits the station published in the early part of the year Bulletin No. 9, "Citrus Fruits in Hawaii," which contains cultural instructions relating to soils, propagation by seeds, budding and grafting, irrigation, fertilizing, pruning, etc. Since the publication of the bulletin some interesting forms have been observed which are not there recorded. An orange has been noted which has a decided tendency toward the navel type and lacks nothing in flavor.

The citrus nursery at the station contains stocks of several species which are ready for budding.

MANGOES.

Bulletin No. 12, "The Mango in Hawaii," has also been published during the year and contains cultural instructions, methods of propagation, description of a large number of varieties, and notes on insects and diseases. The mango is destined to become one of the important tropical fruits of the American markets. That it can be shipped in cold storage has already been demonstrated, and the West Indies will probably supply the eastern markets in the near future. Hawaii should supply the Pacific slope with mangoes and even send some as far east as Chicago.

There is but one serious obstacle which may hinder this Territory from building up a large and important mango industry. The presence of the mango weevil (*Cryptorhynchus mangiferæ*) in Hawaii will be a serious hindrance to the progress of the industry so long as its ravages remain unchecked. All fruit which is under the suspicion of containing this insect will most certainly be quarantined. It is the important duty of the Territory in its own interests to take most stringent measures to control and destroy this insect. It is a duty also to the whole American mainland, since the insect is one that is likely to be introduced in hand baggage, or even in pockets, in spite of the most rigid inspection. A few thousand dollars spent now in efforts to stamp out the pest would mean a saving of millions in the future.

This station is making a collection of trees of all the finest varieties available and will propagate them on seedling stock.

DISTRIBUTION OF BLUEFIELDS BANANAS.

The Bluefields bananas which were introduced in cooperation with the Territorial board of agriculture and forestry have been cared for and multiplied sufficiently to warrant a general distribution throughout the island group. Over 500 suckers and large corms have been distributed, which would probably be equivalent to fully 1,000 suckers. These have been placed in lots of from 2 or 3 to 50, the size of the lot being determined by the locality and the facilities offered for cultivation. The distribution has been made with the understanding that those who have received the plants will care for the same, noting their growth and production and reporting from time to time. It has further been agreed that the Government shall receive from each grower a number of plants equal to that given if at any time in the future such should be needed for a further distribution. This variety of bananas, as has been stated in previous reports, was introduced because of certain advantages which it holds as a commercial banana. It is more easily shipped and is the variety which is best known in the American markets.

THE ROSELLE.

Among the plants which have been cultivated in the experimental plats during the year is the roselle (*Hibiscus sabdariffa*). The fleshy calyx of this fruit and the seed pod while young and tender are used in the manufacture of very excellent jam and jelly. The experiments conducted show the plant to be well adapted to local conditions. It produces a heavy yield of fruit per acre, amounting to 6,000 or 7,000 pounds under average conditions. The plant will tolerate a reasonable amount of dry weather, but responds freely to the application of water and produces more heavily. The seed is sown about March and the plants reset in the field when about 6 or 8 inches high, at distances about 4 by 6 feet if irrigation is to be practiced or if rainfall is abundant. In dry localities 4 feet by 4 feet will be sufficient. A new crop of larger area has been planted to continue the experiments through the coming year.

SYSTEMATIZING OF RECORDS.

Photographic records.—The photographs of the horticultural work have been indexed so as to make them readily available. All negatives have been filed in drawers in an index case and have been numbered consecutively in different series, determined by the size of the negative. One print from each negative has been mounted on especially prepared sheets and filed by subjects in a loose-leaf binder.

The number corresponding to that of the negative is placed under the print. By reference to this number the negative can be found immediately. The subject index is provided so that in a very few minutes it is possible to determine just what photographs are in the station file on any subject. This has already been of great convenience and should prove more valuable as the number of photographic records increases.

Records of plants.—The system followed in recording the planting of seeds, cuttings, tubers, etc., and of growing plants received from outside sources, has been simply that of consecutive numbering in an accession book where the date of planting is also recorded, the same number being placed upon labels in the pots, flats, or field. A card index arranged alphabetically has been made for convenient reference to plants in the propagating houses or fields. The cards contain the scientific name, the common name, if any, the variety, the date of planting, the sources from which received, the places where planted, and other important data.

The following is a list of some of the accessions which have been made during the year ending June 30, 1906:

Accessions by the horticultural department, 1906.

Scientific name.	Common name, or variety.	Remarks.
Citrus aurantium sinensis	Hawaiian summer orange	
Passiflora quadrangularis	Granadilla	
Mangifera indica	Mango	For stock in nursery.
Manihot glaziovii	Ceara rubber	Germination test.
Mangifera indica	Mango	Seeds of selected varieties.
Do	do	Experiments with position of placing seeds.
Persea gratissima	Avocado	Nursery stock.
Nephelium litchi	Litchi	Do.
Ananas sativus	Natal pineapple	S. P. I. 9634.[a]
Thysanolæna agrostis	Ornamental grass	S. P. I. 14922.
Coffea liberica	Liberian coffee	
Musa sapientum	Banana Manzano	From Porto Rico Experiment Station.
Do	Banana Puano	
Do	Banana Morado Blanco	
Do	Banana Johnson	
Do	Banana Morado	
Do	Banana Datil	
Do	Banana Macho	
Nephelium longana	Longan	
Coffea sp	Harras coffee	S. P. I. 11354.
Anona cherimolia	Cherimoyer	S. P. I. 9466.
Quebrachia lorentzii		S. P. I. 6345.
Erythroxylon coca		S. P. I. 6447.
Cissus sp		S. P. I. 7383.
Harpephyllum caffrum	Kafir plum	S. P. I. 9616.
Mimosa afzalioi		S. P. I. 3783.
Erythrina canna		S. P. I. 3787.
Tamarindus indicus		S. P. I. 3780.
Ficus carica	Caprifig	S. P. I. 6780.
Carica quercifolia		S. P. I. 8960; produces the vegetable pepsin of commerce.
Garcinia sp		S. P. I. 9569.
Cæsalpinia gilliesii		S. P. I. 8935.
Maytenus boaria		S. P. I. 8921.
Grabowskia glauca		S. P. I. 8956; hedge plant.
Anacardium occidentale	Cashew	S. P. I. 12809.
Psidium sp	Guava	S. P. I. 11726; a large red variety.
Mangifera sp	The Saigon mango	S. P. I. 11645.
Psidium sp	Guava	S. P. I. 13803; an Argentine guava.

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[a] Seed and Plant Introduction Number, U. S. Department of Agriculture.

Accessions by the horticultural department, 1906—Continued.

Scientific name.	Common name, or variety.	Remarks.
Santalum album	White sandalwood	
Mimusops elengi		
Erythrina suberosa		
Bixa orellana		
Pentzia virgata		A composite, valuable as fodder.
Mangifera indica	Douglas Bennett's Alphonse mango.	S. P. I. 8727.
Do	Totafari	S. P. I. 8732.
Spondias lutea		S. P. I. 9009.
Musa sp	Banana	S. P. I. 13568.
Palisota bartori		
Eriodendron anfractuosum		S. P. I. 14813
Strychnos nux vomica		
Musa sumatrana	Ornamental banana	
Musa rhodochlamys	do	
Musa superba	do	
Carica papaya pyriformis	Papaya	
Musa ornata rosea	Ornamental banana	
Musa religiosa	do	
Musa martinii	do	
Musa gillettii	do	
Acacia giraffæ		
Acacia semperflorens		
Asparagus plumosus blampiedii		
Asparagus plumosus nanus		
Asparagus springeri		
Asparagus decumbens		
Hibiscus rosa-sinensis	Punicens (?)	
Bauhinia montana		
Bauhinia purpurea		
Bauhinia esculenta		
Ipomœa umbellata	Morning-glory	
Ipomœa setosa	do	
Kickxia elastica	Silk rubber	
Citrus decumana		
Psidium cattleyanum	Strawberry guava	
Coffea arabica	Coffee	From Cape Verde Islands.
Gloxinia hybrida robusta		
Nicotiana sanderæ		
Monstera deliciosa		S. P. I. 15673.
Do		From local plants.
Brachychiton populneus	Carryong tree	
Diospyros ebenaster	Sapote, negro wood	
Ipomœa batatas	Sweet potato	21 varieties.
Persea indica		S. P. I. 16133.
Coffea zanguebariæ		S. P. I. 12897.
Vanilla planifolia	Vanilla	
Ricinus lauricariensis		
Castilloa elastica	Central American rubber tree	
Canavalia sp		S. P. I. 17957.
Bauhinia kurgii		S. P. I. 17955.
Eugenia punicifolia		S. P. I. 17956.
Anona muricata	Soursop	
Artocarpus incisa	Breadfruit	
Artocarpus integrifolia	Jackfruit	
Chrysophyllum cainito	Star apple	
Citrus medica limon	Sicily lemon	
Cucurbita lagenaria villosa		
Cucurbita sp		S. P. I. 15937.
Agave rigida elongata	Henequen	
Crotalaria juncea		
Vitis spp	Grapes	About 100 varieties of wine and table grapes.

ORGANIC NITROGEN IN HAWAIIAN SOILS.

By E. C. SHOREY,[a] *Chemist.*

INTRODUCTION.

The importance of the nitrogen problem in agriculture has never been more generally recognized than at the present time.

A recent writer on the subject has stated that the nitrogen in the air covering 5 acres of the earth's surface is equal to that contained in 1,000,000 tons of nitrate of soda, the amount consumed annually in Europe.[b]

Briefly stated, the nitrogen problem is as follows: So far as known none of the higher plants constituting ordinary agricultural crops obtain their nitrogen in any other way than through the soil. The nitrogen of the soil has been at some time the free nitrogen of the air. The processes by which this free nitrogen has become fixed in the soil are not all definitely known. It is known, however, that they are slow. Of the elements taken from the soil by plants there is, as a rule, in the soil and the rocks from which soils are being formed an abundant supply of those of a mineral nature. Moreover, these elements after the growth and consumption of a crop find their way for the most part back to the soil. On the other hand, the nitrogen taken from the soil by growing plants is ultimately in large part returned to the air as free nitrogen.

We have, then, two cycles of an opposite nature. The mineral ingredients of rocks become part of the soil, are taken up by plants, and then by decay or consumption by man or animals are returned to the soil to begin the cycle again. With nitrogen we have the free nitrogen of the air becoming fixed in the soil by slow natural processes, then becoming a part of growing plants, and on the decay or consumption of these plants becoming again free nitrogen of the air.[c] The nitrogen problem arises because under the conditions incident to civilization this cycle is not balanced. The growing of crops, the feeding of stock, and man return free nitrogen to the air faster than the processes of nature fix it in the soil again. The problem, then, is how to aid or supplant nature's processes and fix or render available for the growth of plants the free nitrogen of the air by artificial means.

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[a] Transferred to Bureau of Soils, U. S. Department of Agriculture, December 8, 1906.

[b] P. A. Guye, Paper read before the Swiss Society of Natural Science, 1906.

[c] The statement given above of the relation of plants to the nitrogen of the atmosphere is intended to be most general in character. The cycles are seldom as simple as stated, and the contention made by T. Jamieson (Agr. Research Assoc. [Scot.] Rpt., 1905, pp. 81) that plants utilize the free nitrogen of the air through specialized hairs on the leaves is ignored as not being proven.

There is no doubt that this problem will be solved. It has been attacked from several points by many workers, and along two lines progress has been made to the extent that the problem now is to reduce the cost of production.

There is, however, one phase of the nitrogen problem which has not received the attention it warrants. Many soils contain relatively large amounts of nitrogen. On many such soils containing nitrogen sufficient for many crops it has been found profitable to use nitrogenous fertilizers. This is usually explained by stating that the soil nitrogen is not available.

There are in Hawaii thousands of acres of which the soil contains 20 tons of nitrogen per acre-foot, and a pertinent question in this connection is, why apply nitrogenous fertilizers to such soils; or, to put the question in another form, why can not some of this nitrogen stored in the soil be made to perform the functions of the nitrogen applied in fertilizer, whatever these may be? To answer these and many other questions suggested by this condition, it is necessary to know something about the nitrogenous compounds in the soil. When, however, we face this question, we find that there is absolutely no definite knowledge regarding the chemical composition or constitution of these bodies.

With the belief that how to utilize the nitrogen already in the soil is an important phase of the nitrogen problem, and with the aim to add something to our knowledge of the chemical composition and constitution of the nitrogenous compounds in the soil the soil studies of which the present paper is the first part were undertaken.

NITROGEN IN HAWAIIAN SOILS.

Hawaiian soils differ from those of the American mainland in several respects. Maxwell[a] has pointed out some of these, particularly the highly basic character of Hawaiian soils. Among the important points of difference is one which may be a difference of degree rather than of kind. This is the large amount of organic matter and nitrogen contained in them. Many analyses of Hawaiian soils, by several methods, have been made, but few have been published. Among the general statements regarding the average nitrogen content of Hawaiian soils which have been published the following are the most important. Eckart[b] states the average nitrogen content of Hawaiian cane soils as follows: Oahu, 0.119 per cent; Maui, 0.222 per cent; Kauai, 0.246 per cent;

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[a] Lavas and Soils of the Hawaiian Islands, Honolulu, 1898.

[b] Hawaiian Sugar Planters' Sta., Div. Agr. and Chem. Bul. 15, p. 7.

and Hawaii, 0.388 per cent. Maxwell[a] states the average nitrogen content of upland and lowland cane soil to be upland, 0.456 per cent; lowland, 0.195 per cent. In a later publication the same writer[b] gives the average nitrogen content of 48 samples of cane soil from districts on Hawaii as follows:

Average nitrogen content of Hawaiian soil.

District.	Number of samples.	Nitrogen.
		Per cent.
Kohala	19	0.515
Hamakua	14	.572
Hilo	6	.633
Do	2	.840
Kau	7	.482

Hartmann has published analyses of 12 samples of soil from the plantation of the Onomea Sugar Company on Hawaii, showing a nitrogen content ranging from 0.56 per cent to 0.89 per cent.[c]

Soils above the elevation at which cane is grown are, as a rule, still higher in nitrogen. This is particularly true of the upland soils of Hawaii. Maxwell[d] states the average nitrogen content of the coffee lands in this section to be 1.237 per cent.

The writer has examined soils as to their nitrogen content, from the upper lands throughout the Territory, the amount ranging from 0.30 per cent to 2.20 per cent; and it is thought that a conservative estimate of the nitrogen content of the uplands in cultivation is somewhat as follows. The upland soils on the islands other than Hawaii contain from 0.3 per cent to 0.5 per cent nitrogen, the upper cane soils and those of the adjoining coffee lands on the windward side of Hawaii contain from 0.75 per cent to 1.25 per cent nitrogen, and limited areas on Hawaii contain as much as 2.2 per cent.

The organic matter in these soils as determined by loss on ignition is proportionately high, and the same is true of the humus as determined by the chemical methods at present in use.

As is usually the case with highly organic soils these are very retentive of moisture. Soils containing 10 to 12 per cent humus, which corresponds roughly to 0.75 per cent to 1.0 per cent nitrogen, generally contain when air dried 15 per cent to 20 per cent moisture. The determination of moisture in soils of this character, by loss in weight on drying at 100° C., has been checked in a number of cases by passing a current of dry air through the soil at 100° C. and then into a drying tube containing strong sulphuric acid. The moisture determined by increase of weight of the drying tube has agreed with the loss in weight of the soil; the sulphuric acid was not colored and did not contain nitrogen, showing that the loss in weight is not organic matter.

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[a] Lavas and Soils of the Hawaiian Islands, p. 67, Honolulu, 1898.

[b] Hawaiian Sugar Planters' Sta., Div. Agr. and Chem. Bul. 2, p. 3.

[c] Hawaiian Planters' Mo., 16 (1897), p. 171.

[d] Lavas and Soils of the Hawaiian Islands, p. 67, Honolulu, 1898.

While soils unusually high in nitrogen are very common in Hawaii, there are also some very low in this constituent; some containing as little as 0.05 per cent. These soils are found, for the most part, on the lowlands, especially on Oahu, and some cane lands of this character are the most productive in the Territory if not the most productive in the world. While the productiveness of these soils is no doubt in a large measure due to favorable conditions, such as temperature, texture of soil, absence of high winds, and abundant irrigation, no one who has followed their development can doubt that it is also due in no inconsiderable part to the use of fertilizers, especially the application of nitrate of soda.

The scientific investigation of Hawaiian soils has, up to the present time, been confined almost altogether to those devoted to the growth of cane, and as a result of the work of the experiment station of the Hawaiian Sugar Planters' Association fertilizers are now used almost universally on Hawaiian sugar plantations. Nitrogenous fertilizers constitute a considerable portion of those used. For the crop of 1903 Hawaiian planters used 6,000 tons of nitrate of soda and 2,500 tons of nitrogen in other forms.[a]

Crawley[b] says more is spent in Hawaii for nitrogenous fertilizers than for all others combined.

Most of the land in Hawaii available and suitable for crops such as coffee, tobacco, pineapples, etc., is above the cane level and relatively of high nitrogen content. Now, in view of the fact that planters on the lowland find it profitable to use large quantities of nitrogenous fertilizers, what is the proper course for the grower of other crops on the uplands, where thousands of tons of nitrogen are apparently locked up in the soil?[c]

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[a] C. F. Eckart, Hawaiian Sugar Planters' Sta., Div. Agr. and Chem. Bul. 9, p. 62.

[b] Hawaiian Planters' Mo., 25 (1906), p. 222.

[c] The average weight of an acre of Hawaiian soil to the depth of 1 foot is 3,888,000 pounds. (J. T. Crawley, Hawaiian Planters' Mo., 21 (1902), p. 359.) Using this weight as the basis of calculation we have the following figures:

Nitrogen per acre-foot of Hawaiian soil.

Nitrogen soil.	Nitrogen per acre-foot.	Equivalent in nitrate of soda per acre-foot.
Per cent.	*Pounds.*	*Pounds.*
0.05	1,944	14,034
.10	3,888	28,068
.50	19,440	140,340
1.00	38,880	280,680
2.00	77,760	561,360

Or, assuming that the nitrogenous compounds in the soil contain the same amount of nitrogen as protein, we have for 1 per cent nitrogen in the soil 126 tons of nitrogenous compounds per acre-foot.

Viewed from the standpoint of the cane planter, this problem presents itself somewhat as follows: If on a soil containing 0.1 per cent or less nitrogen three or four times as much sugar is produced as on a soil containing 0.1 per cent to 1 per cent; and if in the first case large amounts of nitrogenous fertilizers have been found to be an important factor in producing the crop, may one not temporarily neglect the other factors and ask something about the nitrogen already in the soil in the latter case? Some of the questions which this view of the problem suggests are: (1) In what form does the nitrogen occur in these soils? (2) Can it be converted into nitrates; and if so, under what conditions? (3) Is any of it available in organic form or in any form other than nitrates? (4) Does it occur in any form injurious to plant life?

OUR KNOWLEDGE OF SOIL NITROGEN.

These questions at once suggest the more general one: How much do we know about the nitrogen in the soil? If an attempt is made to answer this question with regard to Hawaiian soils, we find that, despite the fact that there has been little or no investigation of the organic matter in these soils, our knowledge of the composition and constitution of the organic or nitrogenous bodies in them is just as extensive and accurate as that of these bodies in soils elsewhere. In other words, our knowledge of the composition and constitution of these bodies is of the most general nature and may be said to apply to all soils.

Our knowledge of the nitrogenous bodies may be stated shortly as follows: In most soils there is, under ordinary conditions, some nitrogen present as nitrates. This amount is always small and is a constantly fluctuating quantity. There is also in most soils a small amount of nitrogen present as ammonium compounds, and under certain conditions a small amount may be present as nitrites. The amount of nitrogen present as nitrates, ammonia, and nitrites probably seldom exceeds 5 per cent and more often is not 1 per cent of the total. The remainder is organic, and a portion of this is what is known as humus nitrogen.

The term humus as used by agricultural chemists is the name applied to the dark-colored organic matter extracted from the soil by alkaline solutions. The method at present in use for determining humus is essentially that of Grandeau,[a] who applied the term "matière noir" to the extract.

In this extract certain acids—humic, ulmic, crenic, and apocrenic—have been said to exist, but, viewed in the light of modern organic chemistry, these compounds are wholly without standing. A number of chemists have given the percentage composition of these supposed acids, but no two agree. Nothing is known as to their constitution, the presence of the carboxyl group essential to the constitution of an organic acid has never been demonstrated, and all the evidence is to the effect that they are not acids. The lack of standing of these compounds is concisely stated by Cameron[a] as follows: "The existence itself of these acids has never been demonstrated. * * * No satisfactory description of the physical or chemical properties of these supposed acids, their salts, or characteristic derivatives, have been recorded." This statement can not be controverted, and yet in spite of this we find in nearly every treatise on soils from Mulder in 1840 to the present these acids are spoken of with the same assurance that one would speak of citric, tartaric, or any other organic acid the constitution and derivatives of which are well known. Even so recent a writer as Hilgard[b] uses the names of these supposed acids in this way.

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[a] Traité d'analyse des matières agricoles, p. 148. Paris, 1877.

It has been customary for chemists to determine humus by extracting the soil with ammonia and to determine the humus nitrogen in a similar extract made with caustic soda, to obviate the difficulty of distinguishing between the nitrogen of the soil and that of the ammonia when it is used as a solvent. Rimbach[c] has, however, shown that these two solvents do not extract the same amounts of nitrogen from the soil, the greater amount being extracted by caustic soda. This fact is one indication of the complex nature of the soil extract known as humus. The certainty of its complexity is emphasized when we consider that humus is the result of the decay of living tissues in the soil, and is simply a stage in the resolution of living matter into free nitrogen, carbonic acid, and ash ingredients, from which it was formed.

Soil humus, then, may be defined as a group of complex organic bodies containing nitrogen which can be extracted from the soil by dilute alkalis. Some of the bodies in this extract can be precipitated by dilute acids, which precipitate can be dissolved again by alkalis. Some of the bodies included in this group seem to be capable of entering into combination with mineral ingredients in the soil and others have the power of holding, in a form little soluble in water, both mineral and organic compounds which otherwise are freely soluble. In short, humus is a name for a group of bodies of which we know very little, and this meager knowledge is remarked in nearly every work on agriculture. For instance, King[d] says: "The humus of soils so far as its chemical composition is concerned is not well understood." Storer[e] says: "Little is known as yet as to the precise chemical composition of humus."

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[a] U. S. Dept. Agr., Bureau of Soils Bul. 30, p. 39.

[b] Soils, pp. 126, 322. New York and London, 1906.

[c] Journ. Amer. Chem. Soc., 22 (1900), p. 695; California Sta. Rpt. 1899–1901, pt. 1, p. 43.

[d] The Soil, p. 94. New York and London, 1897.

[e] Agriculture In Some of its Relations with Chemistry, Vol. II, p. 187. New York, 1897, 7th ed.

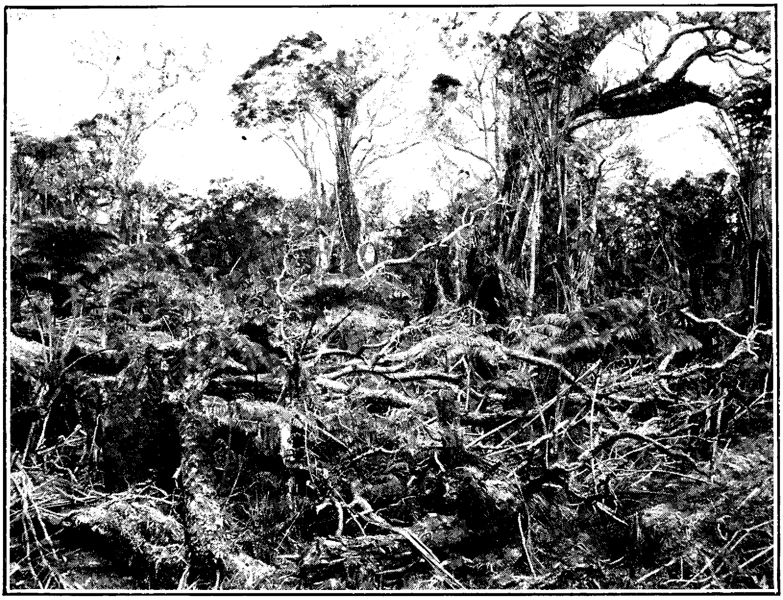

FIG. 1.—VEGETATION ON VIRGIN SOIL, 1,600 FEET ELEVATION, HAWAII.

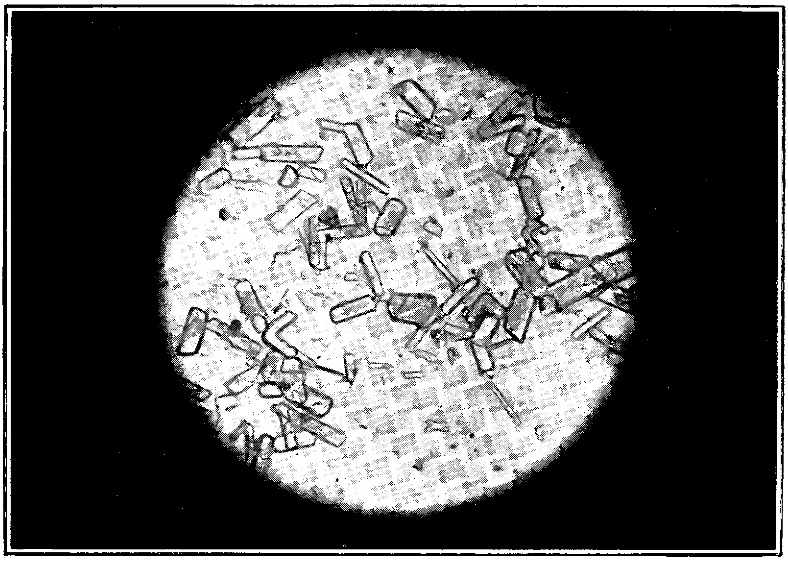

FIG. 2.—PICOLIN CARBOXYLIC ACID FROM POHAKEA SOIL.

There is always a considerable portion of the organic soil nitrogen that is not extracted by alkaline solutions, or is not humus nitrogen as the term is ordinarily used. Of this portion, which often amounts to 50 per cent of the total, still less is known than of humus nitrogen. This group of organic bodies has been given no group name and has been practically ignored, except that it has been considered unavailable in distinction to humus nitrogen as available.

OBJECTS OF STUDY OF SOIL NITROGEN.

The objects in mind in undertaking a study of the nitrogenous compounds in Hawaiian soils were—

(1) To determine more definitely than is now known the chemical composition and constitution of the group of bodies known as humus.

(2) To determine the identity and constitution of organic nitrogenous bodies other than humus.

(3) To determine to what extent the bodies studied under (1) and (2) can be nitrified and under what conditions.

(4) To determine whether organic nitrogenous bodies in the soil can be directly assimilated by plants.

(5) To determine whether any organic nitrogenous bodies in the soil are poisonous or injurious to plants.

SPECIAL SOIL STUDIED.

In attempting to carry out the work so planned it was decided to confine the preliminary work to one soil, typical of a large area fairly high in nitrogen. For this purpose soil was chosen from Pohakea, Hawaii, at an elevation of 1,600 feet (Pl. III, fig. 1). The analysis of this soil by official methods gave the following figures:

Mechanical analysis.

[Soil passed 2-millimeter sieve and analysis calculated to soil free of water and organic matter.]

	Per cent.
Fine gravel, 1–2 mm	25.772
Coarse sand, 1–0.5 mm	17.697
Medium sand, 0.5–0.25 mm	10.498
Fine sand, 0.25–0.1 mm	21.856
Very fine sand, 0.1–0.05 mm	13.018
Silt, 0.05–0.005 mm	9.129
Clay, 0.005–0.0001 mm	2.030

Chemical analysis.

[Soil passed 0.5 millimeter sieve.]

	Per cent.
Moisture	19.540
Organic matter and combined water	28.360
Insoluble	19.320
Iron and alumina	28.797
Lime	.300

	Per cent.
Magnesia	0.631
Sulphuric acid	.343
Phosphoric acid	.703
Potash	.077
Nitrogen	.728
Humus	12.470
Humus nitrogen	.560

Larger samples taken at a later date showed some variation from these figures, the nitrogen varying from 0.700 per cent to 1.010 per cent.

The location of this soil is in the coffee district on the windward side of the island of Hawaii. The samples were taken from land which had been cleared a short time, but had borne no crop. Land in this section before clearing is covered with a tangled growth of ferns, tree ferns, and forest trees, chiefly ohia (*Eugenia malaccensis*), and the soil has been formed in place by the decay of this luxuriant vegetation mixed with the disintegrated lava which forms the basis of all Hawaiian soils. This district is on the rainy side of the island, but is subject at times to severe drought. A record of the rainfall for the last ten years at 1,450 feet elevation a few miles from this location shows the following figures: Highest annual rainfall, 275.46 inches in 1902; lowest, 52.62 inches in 1897; highest monthly rainfall, 93.39 inches in March, 1902; lowest, 0.09 inch in December, 1899. A period of drought occurred in 1901, the rainfall being, May, 0.46; June, 0.21; July, 1.07; August, 0.26, and September, 0.70 inches. In the following year the rainfall for the same months was, May, 29.88; June, 12.65; July, 2.48; August, 32.62, and September, 8.06 inches.

The temperature in this district, as throughout the Territory, is fairly equable, seldom being as low as 55° F. or higher than 85° F. The formation of a soil rich in nitrogen and organic matter under such conditions is somewhat at variance with the generally accepted ideas regarding such soils. Theoretically, one might expect, with a moderate to high temperature, heavy rainfall alternating with dry weather, and a porous, easily drained soil, that the organic matter resulting from vegetable decay would rapidly disappear or be resolved into its elements as the final stage of such decay. That such has not been the case indicates some organic form very resistant to further action by the agents active in the soil. Whether this resistant form is one depending on organic constitution, one of combination with the mineral ingredients of the soil, or one of absorption is of course not known.

GENERAL PROPERTIES OF THE SOIL.

In addition to the general properties already noted this soil presents the following general characteristics:

Solubility.—The behavior of the nitrogenous compounds with regard to a number of solvents is shown by the following figures, the nitrogen dissolved being stated as per cent of the soil. The soil was that which passed a 1-millimeter sieve, and the total nitrogen was 0.862 per cent.

Solubility of the nitrogen compounds of the soil.

Solvent.	Nitrogen in solution, calculated to original soil.
	Per cent.
Distilled water, 30° C. 1 hour	0.005
Distilled water, 100° C. 1 hour	.022
Distilled water, 125° C. 3 hours	.050
95 per cent alcohol, 30° C	None.
12 per cent hydrochloric acid, 30° C. 1 hour	.002
12 per cent hydrochloric acid, 100° C. 7 hours	.623
5 per cent caustic potash, 100° C. 1 hour	.728
Acid pepsin, 40° C. 1 hour	.076
Cuprichydrate, 100° C	.011
2 per cent permanganate of potash, 100° C. ½ hour	.516

From these figures and other observations which have been made, the conclusion is warranted that the nitrogenous bodies in the soil are extremely insoluble in common solvents at the ordinary temperature, with the exception of dilute alkalis, as in the determination of humus. Acids and oxidizing agents at boiling temperature render a large portion soluble, this solubility being evidently due to change in constitution.

Ammonia.—The soil on distillation with excess of magnesia gave nitrogen as ammonia 0.007. Using milk of lime instead of magnesia and distilling in a current of steam, the nitrogen obtained as ammonia was 0.035 and on distillation with direct heat 0.053. Distillation with 1.5 per cent caustic soda gave nitrogen as ammonia 0.154. It is seen from these figures that only a small portion of the nitrogen in the soil can be present as ammonium compounds, but a large amount is readily split off as ammonia by alkalis at an elevated temperature.

Dry or destructive distillation of the soil gives an alkaline distillate containing ammonia. The alkalinity of this distillate was found to be equivalent to nitrogen as ammonia 0.168, the total nitrogen in the distillate being 0.145. In addition to ammonia this distillate contains pyridin or some of its homologues, and a portion of the alkalinity is due to these bodies. This seems to indicate the presence of some pyridin ring compound in the soil.

DECOMPOSITION PRODUCTS.

Much of our rather meager knowledge of the complex protein molecule is due to the study of its decomposition products. When the protein molecule is dissociated, whether the means be chemical in the laboratory or the agency of ferments in decay, it splits along certain lines of cleavage and bodies are obtained which have been designated primary dissociation products. The establishment of the constitution of these bodies has thrown some light on the constitution of the parent body. The reagent most commonly used in the laboratory in bringing about this dissociation has been boiling dilute acids. The literature of this subject is now quite voluminous and dates from 1818, when Proust[a] discovered leucin in cheese. A good general account of the subject is given by Kossel and Kutscher.[b]

With regard to the nitrogen in the soil, it is safe to assume that a large part, if not all, of it has been at some time a component part of the protein molecules in living plants. Whatever may have been the initial stage in the transfer of the free nitrogen of the air to the soil, the stages immediately preceding the final step have no doubt been living protein, dead protein, decaying protein. Such being the case, one might expect some parallel between the compounds resulting from the decay of plant compounds in the soil and the dissociation products obtained in the laboratory. In the soil, however, the study of the process of dissociation is complicated by several factors; the large amounts of mineral matter present may enter into combination with the organic bodies formed; certain organic bodies formed have an absorptive power for others; and, finally, while the process is going on these dissociation products are subject to loss through solution and leaching from the soil or subject to further complex changes by the numerous agents at work in the soil. We would expect, then, that the soil would contain plant residues not yet dissociated and such products of dissociation as had resisted leaching, some probably in combination with the mineral matter in the soil, others absorbed, and still others present as secondary products.

With this in mind a method of classifying the dissociation products of protein proposed by Osborne and Harris[c] was applied to the soil. This method, which is a modification of that of Hausmann,[d] is in short at follows:

Boiling the material with dilute acid, removing the excess of acid by evaporation, determination of the nitrogen present as ammonia by distilling with magnesia, determination of the nitrogen in the magnesia precipitate, precipitation of the basic nitrogen in the filtrate by phosphotungstic acid, and the determination of the nonbasic nitrogen by difference. In applying this method to soil 10 grams were boiled under a reflux condenser with 100 cubic centimeters, 12 per cent hydrochloric acid, usually for seven hours, and the insoluble residue boiled for the same time with 100 cubic centimeters sulphuric acid, the process as outlined being carried out with the two solutions separately, the removal of excess of acid by evaporation of course being applied to the hydrochloric-acid solution only.

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[a] Ann. Chim. et Phys., 10 (1819), p. 40.

[b] Ztschr. Physiol. Chem., 31 (1900), p. 165.

[c] Jour. Amer. Chem. Soc., 25 (1903), p. 323.

[d] Ztschr. Physiol. Chem., 27 (1899), p. 95.

In treating the soil with boiling hydrochloric acid of this strength the amount of nitrogen rendered soluble was found to be increased very little on prolonging the boiling more than two hours. The difference between boiling two hours and fourteen was found to be 0.08 per cent nitrogen, the total amount in solution at the end of fourteen hours being 0.630 per cent. During the first hour of boiling there is much frothing, and if the operation is stopped at this stage a somewhat viscous solution is obtained very difficult to filter. This viscous character of the solution wholly disappears after two hours, and it is evident that the prolonged boiling brings about some change in constitution, and is not merely a separation of organic bodies from combination with the basic elements in the soil.

This method when applied to the soil gave the following figures:

Solubility and forms of nitrogen in acid solutions.

	HCl solution.	H_2SO_4 solution.	Total.
	Per cent.	*Per cent.*	*Per cent.*
Nitrogen in solution	0.623	0.112	0.735
Nitrogen as ammonia	.119	None.	.119
Nitrogen in MgO precipitate	.280	.105	.385
Basic nitrogen	.140	.005	.145
Nonbasic nitrogen	.084	.002	.086

Considering these dissociation products in detail, the following points should be noted. The whole of the ammonia is that obtained from the hydrochloric-acid solution. The ammonia already present in the soil was 0.007, leaving 0.112 split off by the action of boiling acid. Practically all investigators agree that ammonia is one of the primary dissociation products of boiling protein with acids.[a] Determination of ammonia in this method by distilling with magnesia is open to the objection that ammonia may be formed as a secondary product; but neglecting the error due to this, which must be small in any case, we have the following conclusion warranted by the figures obtained. There is present in the soil 0.007 ammonia as the residue of previous dissociation through decay, and if subsequent dissociation in the soil should be of a similar character to that produced by acids in the laboratory there would finally result 0.112 ammonia. Just how far the two methods of dissociation are similar, and how much of the ammonia would remain fixed in the soil and how much lost by leaching or further chemical change, is of course unknown.

The nitrogen in the magnesia precipitate has been by most investigators designated "humin nitrogen." The term humin was first used by Berzelius[b] instead of "ulmin and geine," which had been applied to the dark-colored constituents of vegetable mold. Mulder[a] showed that brown or black substances of a similar nature were formed on boiling albumins with strong acids; and later other investigators showed that humin substances were formed in the same way from many other bodies, especially carbohydrates.[b]

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[a] O. Nasse, Arch. Physiol. [Pflüger], 6 (1872), p. 589; 7 (1873), p. 139; 8 (1874), p. 381. H. Hlasiwetz and J. Habermann, Liebig's Ann. Chem., 169 (1873), p. 150. A. Kossel and F. Kutscher, Ztschr. Physiol. Chem., 31 (1900), p. 165. E. Fischer, Ibid., 33 (1901), p. 151; 33 (1901), p. 177; 35 (1902), p. 70; 36 (1902), p. 462.

[b] Poggendorff's Ann., 44 (1838), p. 375.

When the body acted on contains nitrogen the resulting humin substance also contains nitrogen, and the same is true for iron and sulphur. Schmiedeberg[c] has shown that these humin substances present a great resemblance in properties and chemical composition to the dark pigment in hair and skin. These pigment substances are known as melanins, and he has proposed for the humin substances the name melanoidins. The humin substances or melanoidins occurring naturally as the result of decay or produced by chemical reagents in the laboratory should be distinguished from humus. The term humus, as used in soil chemistry, is simply an empirical term for an alkaline extract of the soil made in a certain way. This extract contains the dark-colored humin substances of the soil, but it also contains other nitrogenous bodies. From the alkaline soil extract known as humus, acids precipitate humin bodies, and on filtering a portion of the nitrogen extracted is found in the acid filtrate.

The melanins, the resemblance between which and the humin bodies has been noted, are the dark-colored pigments found in hair, skin, the choroid coat of the eye, and in certain abnormal tissues, such as sarcoma. They are amorphous bodies, and so far as known do not give any special reactions. They differ in composition according to the source, and agree only in having a high carbon and low hydrogen content. Analyses of many of these have been made, some of which are given below.

Composition of melanins from different sources.

Source of melanin.	C.	H.	N.	S.	Fe.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per ct.*
Sarcoma[a]	55.76	5.95	12.3	8-9	0.06
Hair[b]	52.74	3.33	10.51	3.34	......
Skin, negro[c]	51.83	3.86	14.01	3.6	......
Sepia[c]	56.34	3.61	12.34	.52	......
Melanoidin[d]	66.27	5.49	5.57	.9	......
Do.[d]	60.34	4.86	8.09	.95	......

[a] K. A. H. Mörner, Ztschr. Physiol. Chem., 11 (1887), p. 66; 12 (1888), p. 229.
[b] Abel and Davis, Jour. Expt. Med., 1 (1896), p. 361.
[c] M. Nencki and N. Sieber, Arch. Expt. Path. u. Pharmakol., 24 (1887), p. 17.
[d] O. Schmiedeberg, Ibid., 39 (1897), p. 1.

On precipitating the humin substance or melanoidin from a humus extract of the soil made with 5 per cent caustic soda with hydrochloric acid, washing free of acid and drying, there was obtained an almost black body containing 3.16 per cent nitrogen and 18.96 per cent ash. As the humus extract had been passed through a Pasteur filter, the ash constituents were wholly in solution. This ash contained 93 per cent alumina and but a trace of iron. On treating some of the humin substance so obtained with dilute ammonia before drying, a portion was insoluble. The ammoniacal solution on treatment with a slight excess of hydrochloric acid gave a precipitate of humin bodies which on washing and drying was similar in appearance to that first obtained. This body contained 4.9 per cent nitrogen and 8.36 per cent ash.

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[a] The Chemistry of Vegetable and Animal Physiology. Trans. by D. P. H. Fromberg, Edinburgh and London, 1849, p. 153.

[b] L. V. Udránszky, Ztschr. Physiol. Chem., 11 (1887), p. 537; F. Hoppe-Seyler, Ibid., 13 (1889), p. 66; O. Schmiedeberg, Arch. Expt. Path. u. Pharmakol., 39 (1897), p. 1; F. Samuely, Beitr. Chem. Physiol. u. Path., 2 (1902), p. 355.

[c] Arch. Expt. Path. u. Pharmakol., 39 (1897), p. 1.

When the humin substance obtained from a caustic soda extract by precipitation with hydrochloric acid is dissolved in caustic soda and precipitated again with acid, a further quantity of nitrogen is obtained in the acid filtrate. The following figures illustrate this: A humus extract made with 2 per cent caustic soda contained 0.516 nitrogen per cent of soil. On precipitating with hydrochloric acid and washing free of acid there was obtained in the acid filtrate 0.115 per cent nitrogen. A second solution and precipitation gave 0.056 per cent and a third 0.022 per cent nitrogen in the acid filtrate, making a total of 0.193 per cent nitrogen in the humus extract other than in the humin bodies. Although humin bodies from the soil absolutely free of nitrogen have not been obtained, it seems probable that by carrying on the solution and reprecipitation still further this result would be obtained. In any case, the fact that a portion of the nitrogen continues to be extracted by this process indicates that the nitrogen is absorbed rather than in chemical combination in the humin bodies.

In the treatment of pure protein with boiling acids the amount of nitrogen obtained in the magnesia precipitate and classed as humin nitrogen is small; for instance, Osborne and Harris[a] give the following among other figures:

Proportion of nitrogen of proteids precipitated by magnesia.

Protein.	Total nitrogen.	Nitrogen in MgO precipitate.
	Per cent.	*Per cent.*
Wheat globulin	18.39	0.28
Legumin	17.97	.17
Casein	15.62	.21
Gliadin	17.66	.14
Zein	16.13	.16

It is held by some investigators that the formation of humin bodies from protein by this treatment is the result of the action of the acid on some of the primary dissociation products; that is, that they are secondary products.[b] By this method the soil studied gave 0.385

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[a] Jour. Amer. Chem. Soc., 25 (1903), p. 348.

[b] L. Langstein, Ztschr. Physiol. Chem., 31 (1900), p. 49.

humin nitrogen in a solution containing 0.735, or 52.3 per cent. The amount insoluble in 12 per cent acids was 0.2, which is probably of humin nature. On the assumption that this is so, the total humin nitrogen is 0.585, or 56.1 per cent. This represents the humin nitrogen in the soil plus that produced by the action of acids. In the chemical analysis of the soil the humus nitrogen was found to be 0.56, or 76 per cent, but, as has already been pointed out, the humus nitrogen includes other nitrogen than that of the humin bodies. Whether the figure 0.585 given above represents approximately the humin nitrogen which would ultimately accumulate in the soil depends on a number of factors, regarding which our information is indefinite. For instance, it is not known how much of the nitrogen insoluble in acids is humin nitrogen, nor to what extent the magnesia precipitate contains other nitrogenous bodies; and very little is known regarding the agents at work in the soil tending toward the destruction of these bodies.

The nitrogen classed as basic and which is precipitated by phosphotungstic acid is, in the case of protein, that of the diamino acids, of which lysin, arginin, and histidin are the most important. Whether any of these or related bodies are included in this classification when applied to soil has not as yet been determined.

The nonbasic nitrogen, which is determined by difference, is, in the case of protein, made up of the monoamino acids, glycocol, alanin, leucin, and aspartic acid being the most important. As in the case of the diamino acids, we know nothing at present as to what bodies are represented in this division when the method is applied to soils.

The results of the application of this method to the soil may be summarized as follows: Boiling with 12 per cent hydrochloric acid, followed by boiling with 12 per cent sulphuric acid, renders soluble 0.735 out of 0.935 nitrogen in the soil. The insoluble portion is probably humin nitrogen; nothing definite is known regarding it. In the solution 16.1 per cent is in the form of ammonia, all in the hydrochloric-acid solution. More than 50 per cent of the nitrogen dissolved is that classed as humin nitrogen, the humin bodies being dark-colored amorphous bodies containing nitrogen and seeming to be related to the dark-colored pigments or melanins occurring in hair, skin, etc. Some of the nitrogen in the magnesia precipitate may not be humin nitrogen as the term is ordinarily understood. It is noteworthy that after treatment with hydrochloric acid more than 92 per cent of the nitrogen dissolved by subsequent treatment with sulphuric acid is included in the humin nitrogen. Of the two remaining classes—basic or diamino and nonbasic or monoamino nitrogen—nothing is known as yet in the application of this method to soil.

While the results from the application of this method are as yet of the most general nature, and very indefinite, it is one which seems to the writer to promise some light on the constitution of the nitrogenous bodies in the soil. The method has been applied in some of its several modifications to protein by a large number of workers, and most of the decomposition products have been described, both as to composition and constitution, so that in applying it to soil nitrogen one finds a vast amount of information regarding bodies which must be, if not identical, at least closely related to those found in the soil. A study in detail of these bodies included in the several divisions of the classification made by this method is now being made.

ALKALINE SOLUTION.

In treating of the general properties of the soil it was pointed out that treatment with dilute alkalies at the ordinary temperature, as in humus determination, was the only method found of rendering any large proportion of the nitrogenous compounds in the soil soluble without the application of heat, or other treatment, by which solution would be accompanied with more or less decomposition.

Treatment with dilute alkaline solutions results in a dark brown, almost black, solution, the so-called humus extract. From this solution mineral acids precipitate the dark colored humin substances as a flocculent precipitate containing nitrogen. The filtrate from this precipitate is dark red and also contains nitrogen. From this filtrate, on neutralizing with caustic soda, there is thrown down a dirty brown gelatinous precipitate containing nitrogen. When the original extract was made with caustic soda this precipitate contains a large amount of alumina. The filtrate from this precipitate, which is yellow, also contains nitrogen. From the original extract there is thus made a separation into three groups, all containing nitrogen: (1) The humin substances, dark colored amorphous bodies soluble in alkalis, insoluble in water and dilute acids; (2) the dirty colored precipitate, soluble both in acids and alkalis, but insoluble in water, and containing dark colored organic matter, as well as a large proportion of mineral matter; and (3) the neutral yellow filtrate. In addition to containing nitrogen each of these on being dried and heated with lime gives the odor of crude pyridin, so that it is evident a portion of the nitrogen in each is in the pyridin ring form.

The following figures were obtained in making this division. A humus extract made with 2 per cent caustic soda solution contained 0.0399 gram nitrogen per 100 cubic centimeters solution. Making this slightly acid with hydrochloric acid, filtering and washing, the filtrate contained 0.0251 gram nitrogen per 100 cubic centimeters original solution. On neutralizing this acid filtrate with caustic soda, filtering and washing, the precipitate contained 0.0168 gram nitrogen per 100 cubic centimeters original solution. Stated per 100 N. extracted this result is as follows: Division 1, 37 per cent; division 2, 42.1 per cent; division 3, by difference 20.9 per cent.

This solution in cold alkali and the division into three groups each containing nitrogen furnishes a second empirical method of studying the nitrogenous compounds of the soil. While the first method, that of dissociation with boiling acids, can give an insight into the constitution of these compounds only indirectly through their dissociation compounds, the second presents a possibility of studying a portion at least of these compounds in solution unchanged. For this reason this method was taken up first in detail.

PYRIDIN COMPOUNDS IN THE SOIL.

Each of the three groups separated from alkaline solution in addition to containing nitrogen has another property in common, viz, that of giving pyridin or its homologues on heating with lime.

It has already been noted that the soil studied gave on dry distillation some pyridin in the alkaline distillate. The alkalinity of this distillate, which is largely due to ammonia, has varied somewhat according to the manner of distillation. In one distillate pyridin was determined by the method of François,[a] and there was obtained pyridin 0.0773 per cent of the soil, or nitrogen as pyridin 0.0137 per cent of the soil. This method, which depends on the formation of the aurichlorid $C_5H_5NHCl.AuCl_3$ and its insolubility in ether, gives accurate figures with aqueous solutions of pyridin, but how far it is applicable in the presence of the higher homologues of this body, some of which are evidently present in the distillate, is not known. For this reason this figure must be regarded at present as an approximate one only. The chief point in this connection is the formation of pyridin on dry distillation.

Pyridin was first obtained from the oil resulting from the dry distillation of bones.[b] It is also obtained by the dry distillation of bituminous coal, peat, wood, etc. The commercial source at present is coal tar. A number of alkaloids yield pyridin when highly heated, for instance, it occurs in tobacco smoke as a product from nicotine.

With regard to the formation by dry distillation of such substances as coal and peat, some authorities hold that it is due to the reciprocal action of fats and ammonia, the acrolein from the first condensing with the ammonia to form pyridin.[c] This would not apply to the formation of pyridin from alkaloids, which are, for the most part, pyridin ring compounds. Samuely[d] has shown that the melanoidins or humin substances resulting from the dissociation of protein give pyridin on reduction. For this reason there has been a tendency to assume a pyridin nucleus in the protein molecule. Ellinger[a] has, however, suggested for tryptophane, one of the dissociation products of protein, the structural formula

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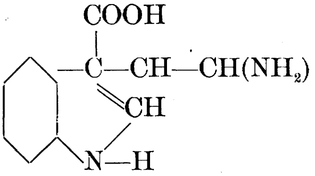
[a] Jour. Pharm. et Chim., 6. ser., 18 (1903), p. 337; Compt. Rend. Acad. Sci. [Paris], 137 (1903), p. 324.

[b] Anderson, Trans. Roy. Soc. Edinb., 20 (1853?), p. 253; abs. in Jour. Prakt. Chem., 54 (1851), p. 36.

[c] Richter, Organic Chemistry, Vol. II, p. 528. Philadelphia, 1902, 3. ed.

[d] Beitr. Chem. Physiol. u. Path., 2 (1902), p. 355.



The establishment of this formula would explain the closure of the pyridin ring in protein dissociation products without the necessity of assuming the existence of the pyridin ring as such in the protein molecule. Ellinger states that a genetic relationship exists between tryptophane and pyridin, and quinolin derivatives in plants, such as alkaloids. Hopkins and Cole[b] have shown that tryptophane is readily changed to dark colored humin substances on boiling with acids or even with water.

The chief point of interest at this stage is whether the formation of pyridin on dry distillation is evidence of the presence of a pyridin compound in the soil.

Viewed in the light of our present knowledge and the theories stated above, the formation of pyridin on dry distillation may be due: First, to the interaction of fatty material and bodies yielding ammonia; second, from melanoidins or humin bodies; third, from some vegetable residue known to contain a pyridin nucleus; and, fourth, from the decomposition of the lime salt of a pyridin carboxylic acid.

If the formation of pyridin is explained by the first method, it means that the pyridin ring is a condensation product of distillation and does not exist as such in the soil. This supposition does not seem likely, for although ether extract of the soil was 0.005 per cent, the soil yielded pyridin after extraction as before.

The possible connection between tryptophane and pyridin, and the readiness with which the former is converted into melanoidins, have been noted, and we have in this a possible explanation of the formation of pyridin. However, accepting the theory that the pyridin is formed from the humin bodies, our lack of knowledge of the constitution of these bodies still leaves unsettled the question whether the pyridin exists as such in the soil. It should be noted in this connection that no trace of tryptophane has been found in any of the soil extracts.

The formation of pyridin according to the third method stated above means that some vegetable compound containing a pyridin nucleus had resisted decomposition and existed unchanged in the soil.

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[a] Ztschr. Physiol. Chem., 43 (1904), p. 325.

[b] Jour. Physiol., 27 (1901), p. 418; 29 (1903), p. 451.

A large number of alkaloids contain a pyridin nucleus, and it is probable that a large number of plants contain compounds of this character which have not been identified or studied. Moreover, the alkaloids are quite resistant to decomposition, and it would not be an unlikely thing to find alkaloids in the vegetable débris making up the organic matter in the soil. In the case of the soil studied no reactions for alkaloids have been obtained in any of the soil extracts made. The only indication of alkaloids was obtained in the distillate resulting from passing steam through soil covered with a 2 per cent solution of caustic potash. From this distillate, which contained a large amount of ammonia, there was obtained a very small amount of a volatile oily substance having the odor of coniin. No reactions for coniin could be obtained, and the amount has been far too small for identification. Its properties so far as determined point to some product of bacterial action related to the ptomaines putrescin and cadaverin.

With regard to the fourth method it is characteristic of a large number of pyridin carboxylic acids that the lime salts of these acids or the acids themselves when heated in contact with an excess of lime give pyridin. This applies also to the carboxylic acids of the homologues of pyridin, the corresponding homologue being obtained. Theoretically this is the simplest explanation of the production of pyridin on dry distillation of the soil. As the total amount of lime in the soil is small and apparently all in combination, this explanation would hold only in the presence of a lime salt of a pyridin carboxylic acid or a similar acid of some homologue of pyridin.

It would seem, then, that the pyridin obtained on dry distillation of the soil is due either to some obscure reaction involving the humin bodies or to the decomposition of the lime salt of some pyridin carboxylic acid.

NEUTRAL SOLUTION.

Returning now to the alkaline solution and the empirical divisions made of it we find that in division 3 we have a neutral solution containing a portion of the nitrogen extracted from the soil. The manner of making the extract and subsequent divisions; treatment with dilute alkalis and acids without the application of heat, is such that it is safe to conclude there has been no change of constitution; or, in other words, that any compound which appeared in the final neutral solution would be the same compound actually present in the soil, the only change being that of combination. A study of this neutral solution offers then the readiest method of arriving at the constitution of some of the nitrogenous bodies in the soil. Working with a solution made with 5 per cent caustic soda and making the division using nitric acid instead of hydrochloric as outlined above the following results were obtained with the neutral filtrate.

On being concentrated to small bulk a small amount of dark flocculent apparently humin substance was precipitated. The filtrate from this gives a voluminous white precipitate with silver nitrate. This precipitate becomes darker on exposure to light and is soluble in ammonia. On decomposing this precipitate with hydrogen sulphid and concentrating the filtrate from silver sulphid to small bulk crystals were obtained quite soluble in hot water, but difficultly soluble in cold. On repeating this process several times the crystals were obtained almost free from color.

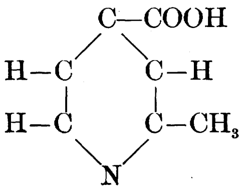
Lead acetate gives with the neutral solution in most cases a slight precipitate, apparently coloring matter. On filtering from this and adding ammonia there is thrown down a heavy yellowish precipitate consisting, of course, in part of basic nitrate. On decomposing this with hydrogen sulphid, neutralizing free nitric acid with ammonia, concentrating to small bulk, adding silver nitrate, and treating the precipitate so obtained as above the same crystalline preparation was obtained. This precipitation with ammoniacal lead acetate and subsequent precipitation with silver nitrate was found to be a readier method of obtaining crystals free from color than direct precipitation as the silver compound.

The crystals prepared in this way, as already stated, are soluble in hot water, little soluble in cold. They are very little soluble in alcohol and insoluble in ether. From solution in hot water on cooling oblique prismatic crystals separate having a very peculiar appearance, giving en masse the impression of being slices or scales and resembling somewhat crystals of benzoic acid. On rapidly cooling a hot, very dilute solution minute crystals, regular in form, are obtained, as shown in Plate III, figure 2.

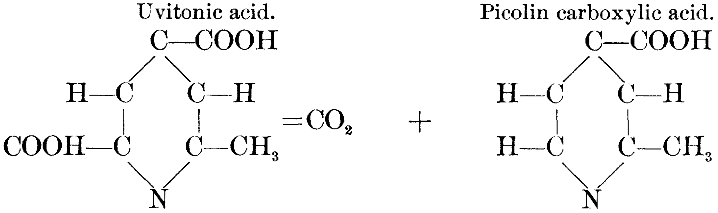
This preparation when heated in an open watch glass sublimes without melting and leaves no residue. The sublimate was found to be the same substance unchanged. Heated in a capillary tube it does not melt at 300° C. The water solution gives no color with ferrous sulphate, and is very faintly acid. The solution neutralized with ammonia gives no precipitate with either barium chlorid, calcium chlorid, cadmium sulphate, or lead acetate. Cupric acetate gives a dark bluish crystalline precipate insoluble in cold water. With hydrochloric acid a compound is formed crystallizing in prisms.

PICOLIN CARBOXYLIC ACID.

The properties of this substance as thus determined point to its being picolin carboxylic acid, or methyl pyridin carboxylic acid. The structural formula of this is:



This acid has been described by Böttinger[a] and was prepared by him by heating uvitonic acid (methyl pyridin dicarboxylic acid) to 274° C. This breaks up as shown below:



The identification of this body has been confirmed by the following determinations. Picolin carboxylic acid crystallizes with one molecule of water of crystallization which it loses at 100° C. A determination of the water of crystallization of the acid from the soil gave 11.34 per cent while that calculated from the formula $C_5H_7NO_2H_2O$ is 11.62 per cent. The hydrochlorid gave Cl 20.50 per cent the calculated Cl for $C_5H_7NO_2HCl$. being 20.46 per cent. Nitrogen in the acid, free of water of crystallization, was found to be 10.02 per cent, that calculated for $C_5H_7NO_2$ is 10.21 per cent. The acid from the soil on oxidation with permanganate of potash yields a body crystallizing in leaflets little soluble in cold water and melting at 239° C. The water solution of this body gives a yellowish orange color with ferrous sulphate. These properties correspond to those of lutidinic acid, one of the pyridin dicarboxylic acids; the picolin carboxylic acid on oxidation yielding lutidinic acid by the oxidation of the methyl group to carboxyl, thus, C_5H_3N, CH_3, $COOH+2O_2=C_5H_3N(COOH)_2+2H_2O$.

This close agreement between the theoretical and determined figures and the properties as determined is sufficient to establish the identity of the substance as picolin carboxylic acid.

The pyridin carboxylic acids include a large number of compounds. Pyridin has five hydrogen atoms replaceable by the carboxyl group. Theoretically there are 19 of these acids possible, all of which are known. All are laboratory products, many of them prepared from alkaloids. In the pyridin ring each of the hydrogen atoms is also replaceable by other groups, e. g. methyl. When this takes place together with replacement of one or more hydrogen atoms by carboxyl we have methyl pyridin carboxylic acid to which group the acid obtained from the soil belongs. Hydrogen atoms in the pyridin ring may also be replaced by other groups so that the possible carboxylic acids is very large. So far none of the pyridin or methyl pyridin carboxylic acids have been found in any plant or natural product but have all been obtained from other related bodies by chemical means.

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[a] Ber. Deut. Chem. Gesell., 14 (1881), p. 67; 17 (1884), p. 92.

There have been six isomeric methyl pyridin carboxylic acids described, picolin carboxylic acid having the CH group in the 2 or α position and the COOH in the 4 or γ position.

In its method of preparation picolin carboxylic acid is of interest in that it can be prepared from its elements. As stated it has been prepared by heating uvitonic acid. This is prepared by the action of ammonia on pyroracemic acid which is obtained by heating racemic acid. This in its turn can be prepared from its elements in a number of ways, ethyl alcohol or carbon monoxid, both of which can be synthesized, being the starting point.

The amount of this acid obtained in a pure form from the soil by the method stated has been small, it being necessary to work with several kilos of soil to obtain enough for the determinations made. No attempt has been made to make quantitative determinations, and the amount obtained has been two to three hundred parts per million of soil, several times the amount of nitrates present under the most favorable conditions.

Picolin carboxylic acid has been obtained from several other Hawaiian soils, including one very heavy clay soil containing but 0.06 per cent nitrogen, so that it would seem not to be confined to highly organic soils.

Mainland soils in quantity have not been available for examination; however, from small samples on hand of soil from eastern States, small quantities of crystals were obtained having the appearance, physical properties, and behavior in solution of those of picolin carboxylic acid.

RELATION OF PYRIDIN COMPOUNDS TO AGRICULTURE.

It is common in Hawaii for farmers to find virgin soil, especially on the uplands, unproductive for the first years of cultivation. In some cases nothing will grow, as might be expected from conditions of soil and climate, and again certain crops will grow and others will not. This condition is generally relieved by cultivation, but in some cases not wholly so. Various explanations have been given for this condition, including ferrous iron, soil acidity, and lack of one or more of the elements necessary as plant food; but in most cases such examinations as are made in chemical laboratories have failed to reveal anything of this nature. For this reason there is in the minds of very many who have attempted to grow crops in Hawaii a confirmed conviction that there is in such cases something poisonous in the soil. Somewhat similar conditions have been observed in limited locations elsewhere. Aside from this, however, there are many facts in regard to the rotation of crops and the effect produced by certain fertilizing materials, such as stable manure, effects wholly out of proportion to their value as determined by analysis, forcing the conclusion that there exist a whole series of phenomena regarding the relations of plants to the soil that are unexplained and even unmentioned in the current teachings regarding available plant food and fertilization. These general considerations, coupled with exhaustive studies of special soils, have led to the conclusion that in many cases soils do not produce crops for the reason that they contain some body poisonous to the crop grown and not because of lack of plant food.[a] It is not known whether such poisonous bodies are excretions of plant roots or the result of bacterial action on organic compounds in the soil.

It has already been noted that many poisonous alkaloids are pyridin compounds. These alkaloids are plant products and are found in many cases deposited in the seeds. The chemical reactions which precede the secretions of these poisons in the plant are not known, and although they must exist as such in some part of the plant, it is evidently in such form or such place that the life processes of the plant are not interfered with. Experiments indicate that in the germination of seeds containing poisonous alkaloids these nitrogenous compounds are not reassimilated,[b] and so far as the plant is concerned they seem to be either excretions of material for protection or depositions in an insoluble form of material which would injure living protoplasm.

Many fungi can grow on dilute solutions of poisonous alkaloids, and it can not be assumed that because a compound is poisonous to higher animals it will prove so to plants. This can only be determined by experiment.

With regard to picolin carboxylic acid, it is of interest to note its family connections. Uvitonic acid, from which it can be prepared by heating and which differs in composition only by CO_2 and in constitution only by having one COOH group in the place of one H atom, is known to be a strong antiseptic. Further, uvitonic acid on oxidation with alkaline permanganate yields a pyridin tricarboxylic acid. There are five possible isomeric pyridin tricarboxylic acids, the one obtained from uvitonic acid having the carboxyl groups in the positions 2, 4, 6. Another member of this group, having the carboxyls in the positions 2, 3, 4, is also known as an antiseptic, and has been recommended as such in medicine.[a] The structural relationship between these is shown below:

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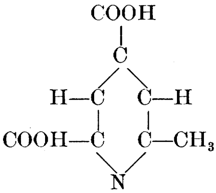
[a] U. S. Dept. Agr., Bureau of Soils Bul. 28. M. Whitney, U. S. Dept. Agr., Farmers' Bul. 257.

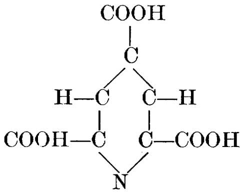
[b] De Vries, Landw. Jahrb., 7 (1878), p. 243. Wotezal, Bot. Jahrb. 41, p. 100. G. Meyer, Bot. Centbl., Beihefte, 6 (1895), p. 61. Heckel, Compt. Rend. Acad. Sci. [Paris], 110 (1890), p. 88.

Uvitonic acid.



Antiseptic

Tricarboxylic acid 2.4.6.



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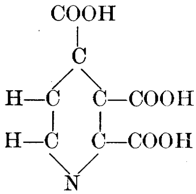
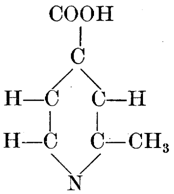
Tricarboxylic acid 2.3.4.



Antiseptic

Picolin carboxylic acid.



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These facts are suggestive, and it would seem very probable some of the pyridin carboxylic acids might have a detrimental effect on growing plants.

With regard to picolin carboxylic acid, which seems to be a normal constituent of soils, no conclusions have yet been reached either respecting its antiseptic properties or its effects on living plants. Investigations covering these points are being now carried on.

In considering the relation of picolin carboxylic acids to agriculture, there are two points which should be especially considered. First, the solubility of nearly all its salts, although the acid itself is little soluble. Experiments indicate that these soluble salts are readily absorbed by the humin bodies, but to what extent has not yet been determined. The second point is that while it is an acid in constitution in virtue of having a carboxyl group, and forms salts with bases, it at the same time can act as a base and forms compounds with mineral acids by direct addition. All of the pyridin carboxylic acids having but one or two carboxyls have this characteristic, and it is only when the number of carboxyls is increased, as in the penta acid, that the power of uniting with strong acids is lost and the acid character becomes prominent. Picolin carboxylic acid, then, is not one which could be considered a factor in considering soil acidity, or the dissolving, or rendering "available," the mineral matter in the soil.

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[a] C. J. Rademaker, Med. Herald, 19 (1887), p. 107.

THE ECONOMIC SEAWEEDS OF HAWAII AND THEIR FOOD VALUE.

By Minnie Reed, M. S.,
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Hawaii has nearly a thousand miles of coast line; as a consequence the native Hawaiians are skillful and daring fishermen and sailors, as well as splendid swimmers. The Hawaiians, like the Japanese, are fond of almost all the products of the sea, and, like them, prize the seaweed very highly for food. Ancient Hawaiians probably seldom ate a meal without some kind of limu[a] or seaweed, and even to-day no Hawaiian feast is considered quite complete without several varieties served as a relish with meats or poi.[b]

Many tons of these seaweeds are gathered and eaten by the Hawaiians annually, besides large quantities are imported from the Orient and San Francisco for the consumption of both the Japanese and Chinese. The seaweed sold in Honolulu alone amounts annually to thousands of dollars.

Before the coming of the white man to these islands the diet of the poorer Hawaiians was largely poi, fish, and limu. Even poi was scarce in times of war or famine, and then the poorer fishermen contented themselves with only fish and limu. Sometimes for weeks no other vegetable food could be obtained but limu, which can be gathered all the year, except during very severe storms. Sweet potatoes, taro, and bananas could only be grown in the good soil, where there was plenty of rain or sufficient water for irrigation. Many of the fishing villages had no fertile land near them, so these people were compelled to go to the mountain valleys to secure all their food except what they fished from the sea. Until the death of Kamehameha the Great (1819) women suffered the death penalty if they ate bananas, cocoanuts, turtles, pork, or certain fish, so that their diet was even more limited than that of the men. They must have suffered greatly during times of famine and war, when their only food came from the sea. Before the coming of the missionaries there were no fruits except bananas, cocoanuts, and the mountain apple, and none of these were ever abundant, except the mountain apple or ohia,[a] which is plentiful only during July and August in the mountain valleys wherever there is a heavy rainfall.

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[a] Limu is the Hawaiian name generally applied to all water plants, and is equivalent to our word algæ. They sometimes include various pond weeds, or fresh-water limu, as nitella, chara, etc. Usually limu means either fresh or salt water algæ that are edible.

[b] Poi is a thick paste made from the root of the taro plant (*Colocasia esculentum*), and takes the place of rice or bread in the native diet. It is made by pounding the moistened boiled or steamed roots with water to smooth paste, which is then slightly fermented.

It was because of this limited food supply, no doubt, that the early Hawaiians learned to use for food almost every living thing, both plant and animal, found along their coasts. Almost every kind of seaweed that could possibly be eaten was used for food by some Hawaiians, while certain of the more attractive algæ were universally used wherever and whenever it was possible to secure them from the sea. The people living in the mountain valleys used, in addition to marine algæ, several kinds of the soft green fresh-water algæ from the streams and ponds. Nothing edible, from tiny shellfish or minnows an inch long to great sharks, escaped the hungry Hawaiian fisherman. Likewise he gathered seaweeds, large and small, and also the fine green algæ of the fresh water to satisfy his hunger for vegetable food. The limu had to take the place of all green vegetables—as onions, lettuce, beets, beans, peas, etc.—as well as fruits, and must have helped very much to vary the monotony of a diet of fish and poi, which were then as now the two staple foods of the native Hawaiians.

There are over seventy distinct species of algæ or limu used for food by the Hawaiians. Of these seventy species not more than forty are in general use. The other thirty or thirty-five are used only by a few people in certain small areas where they are found in limited quantities. There are perhaps a dozen or more common species of algæ, mostly marine, that are termed by the Hawaiians simply limu, or with some descriptive appellation, like limu make, meaning poisonous limu. Each edible limu has its own special appellation besides the generic name limu with which it is combined either as a descriptive adjective or as a suffix.

The following notes and observations have been collected during the last three years from various sources, and from personal study in the markets and along the beaches wherever the limu gatherers were at work collecting or preparing algæ for food. In addition to this, much information has been secured from Hawaiian friends who have very kindly assisted the writer in various ways in collecting both the specimens and data. The writer is especially indebted to Mrs. Emma Metcalfe Nakuina, Mrs. W. L. Bowers, Mrs. Elizabeth Kahanu Gittle, Mrs. Rosina Shaw Leslie, Mrs. Kepoikai, Mr. B. K. Kaiwiaea, Mrs. Deverel, Judge Kahele, and many others for the native names, specimens for study, and descriptions of the methods of preparing them for food. A number of the pupils of the Kamehameha schools from different islands have, with the aid of their relatives, helped secure specimens of their edible algæ with the native names. They have also furnished many notes on the preparation and preservation of algæ for food. The writer is also very greatly indebted to Dr. W. A. Setchell, of the University of California, for identifying and verifying many specimens, and to R. A. Duncan, food commissioner and chemist of the Territory of Hawaii, for analyzing the edible algæ and for the use of his library.

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[a] *Eugenia malaccensis*, in the valleys and mountain slopes in the lowest forest zone. Fruit sweetish, juicy, about size of early June apple, and resembling a red apple, except in flavor.

The following publications have been consulted for tables of analyses and other data: U. S. Dept. Agr., Office of Experiment Stations Circular 46 (rev.), by C. F. Langworthy, Ph. D.; Office of Experiment Stations Bulletins 68, 107, and 159; United States Dispensatory; Analyses of Taro and Poi, report of Dr. E. C. Shorey when food commissioner and chemist of the Territory of Hawaii; Postelsia, the Yearbook of Minnesota Seaside Station, 1901; and Seaweed Industries of Japan and the Utilization of Seaweeds in the United States, by Hugh M. Smith. Bul. [U. S.] Bureau of Fisheries, 24 (1904).

METHODS OF GATHERING LIMUS.

Most of the limu is gathered by native women and children, except that which grows in the deeper or rougher water, far out on the coral reefs, or on exposed rocks, where expert swimming and more strength are required, and also where a boat is usually needed. In such places at least two people are required, and often a party of three or more men and women go together. The women usually gather the limu while the men are fishing and caring for the boat and nets.

The limu gatherers go out at low tide with tin pails, old sacks, and pieces of sharpened iron or an old knife, and scrape the seaweed from the coral or rocks. The seaweed is freed from sand and pebbles and each kind placed in a separate receptacle, if possible. If the limu grows nearer shore in the sand or mud, or floats in near the beach, the women and children wade out, gathering it without any implements, carefully washing out the sand, mud, or small sea animals, and pulling out all inedible limu before placing it in their pails or sacks. They often wade out into the water above the waist, following the tide as it recedes. A few varieties of limu drift ashore, and are simply gathered along the water's edge from the rocks and sand and shaken free from the sand or inedible weeds. The following varieties are often found drifted on the sand or rocks: Limu huna (*Hypnea nidifica*), limu manauea (*Gracilaria coronopifolia*), limu kala (*Sargassum echinocarpum* and *S. cymosum*), and limu lipeepee or limu maneoneo (*Laurencia papillosa*, *L. pinnatifida*, *L. virgata*, *L. obtusata*, and a few other species of Laurencia not yet identified).

Limu uaualoli (*Gymnogongrus vermicularis* var. *americana* and *G. diciplinalis*), limu kohu (*Asparagopsis sanfordiana*), limu aalaula (*Codium muelleri* and *C. tomentosum*), limu lipoa (*Dictyota acutiloba* var. *distorta* and *Haliseris plagiogramma*), and limu lipeepee of several varieties grow far out on the coral reefs or on exposed rocks in the surf. These all have rather tough, firm holdfasts, and a stout sharp knife or chisel is required to loosen them from their supports and strong swimmers to gather them. Those named above are usually gathered by a party in a boat, though sometimes the limu gatherers venture far out on the shallow coral reefs with only their pails or bags and their chisels.

The following varieties of limu grow quite near the tide line along shore, but on exposed black lava rocks in rough water: Limu akiaki (*Ahnfeldtia concinna*), limu loloa (*Gelidium capillacea*, *G. corneum*, *G. filicinum* (?), *G. pulvinatum* (?), *G. latifolium* (?), *G. attenuatum* (?), and *Pterocladia capillacea*), limu uaualoli (*Gymnogongrus disciplinalis*), and limu luau (*Porphyra leucosticta*). These all have very tenacious holdfasts, so generally require a strong, skillful swimmer with a knife or chisel to gather them in large quantities.

Those growing near shore in quiet waters in sand or mud or on small stones are easily gathered with only the bare hands, and usually the older women and children gather these varieties, while the men and the younger strong women gather the varieties growing in the rougher or deeper water. The following are the varieties easily gathered near shore: Limu eleele[a] (*Enteromorpha prolifera*, *E. linza*, *E. intestinalis*, *E. prolifera* var. *tubulosa*, and *E. plumosa*), limu huna (*Hypnea nidifica*), limu manauea (*Gracilaria coronopifolia*), limu pakaeleawaa or limu huluhuluwaena[b] (*Grateloupia filicina*), limu huluilio (*Chætomorpha antennina*, *Ectocarpus* sp. (?), *Centroceras clavulatum*, and *Stigeoclonium amœnum*), limu pahapaha[c] (*Ulva fasciata* and *U. lactuca* var. *rigida*), limu oolu (*Chondria tenuissima* var. *intermedia*), and limu puaki (*Liagora decussata*). There are besides a few other species found only in small quantities, or in certain localities, and only eaten by the Hawaiians in remote districts, or by a small group of families who alone seem to appreciate their flavor. Limu luau (*Porphyra leucosticta*) is one of these which appears in winter or spring after heavy

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[a] Limu eleele is applied to a number of slender thread-like green algæ growing near the mouths of streams in brackish water. Most of them are Enteromorphas. On Maui the edible Enteromorphas are called by some natives limu pipilani.

[b] Limu huluhuluwaena is the native name for *Grateloupia filicina*, generally used on the island of Hawaii and in frequent use on Maui and Oahu, while limu pakaeleawaa is the name always used on Kauai and in common use on Molokai, Maui, and Oahu.

[c] Limu pahapaha is applied to several Ulvas on Oahu, Molokai, Maui, and Kauai, while limu pakaiea is the name for the same Ulva on Hawaii.

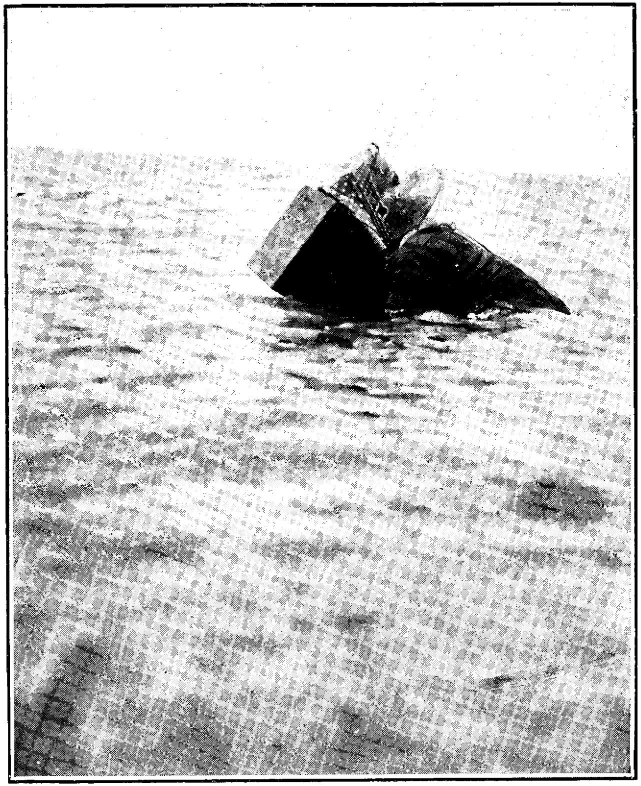

FIG. 1.—USING GLASS-BOTTOMED BOX TO SEARCH FOR LIMU.

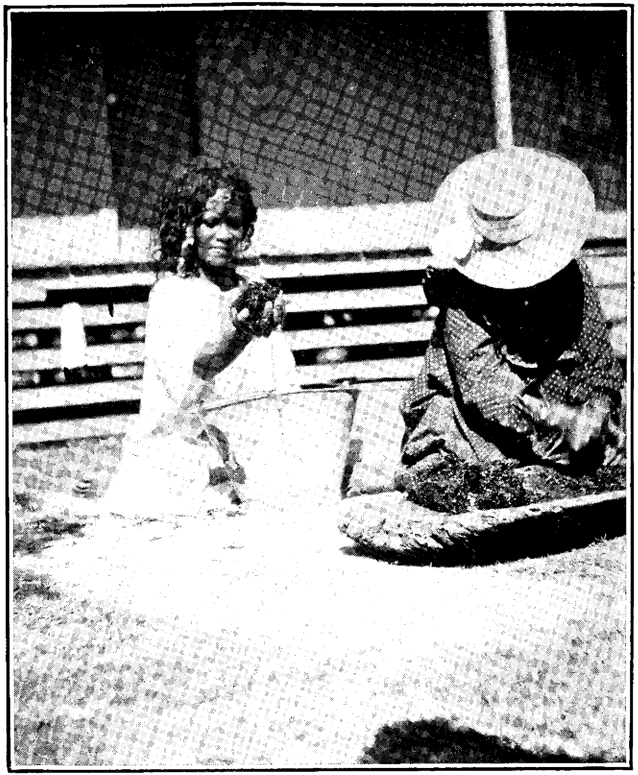

FIG. 2.—CLEANING AND PREPARING LIMU.

storms and last for only a few days. It is found on bold exposed rock constantly dashed by waves, so it is difficult and dangerous to collect it, especially as it is extremely slippery and has to be scraped forcibly from the rocks in small bunches while the collector clings to his support and avoids the heavy waves. He must be sure-footed, quick, and a strong swimmer, if he collect limu luau. Limu eleele must always be floated or dipped out of the water into pails, because it always grows at the mouth of streams in the quiet brackish water, so is full of silt or sand. This is partly washed out as the limu is scraped or floated out with the hands into the pails. This limu is very fine and slippery, like hair, so it must be handled in a different manner from other algæ, and requires much more care to remove the sand, the small, clinging mollusks, and crustaceans.

Occasionally you will see a limu gatherer out on the reef, in water almost to her waist, looking very intently through a square glass-bottomed box, and now and then probing the depths with a sharpened iron rod. The iron rod is used to loosen certain mollusks, limu uaualoli, limu lipoa, limu maneoneo, and also to kill eels and octopi, all of which are highly prized for food. The boxes or square frames with a glass bottom have been recently introduced by the Italian fishermen, and are not in general use even near Honolulu. In Plate IV, figure 1, will be seen a limu gatherer looking through the glass box, probing with the iron bar, with a large bag suspended from her neck, into which she thrusts her limu, mollusks, or squid.[a]

At low tides, when the water recedes, wherever there are flats or shallow coral reefs and quiet water, one can see many natives with bags and old knives wading far out gathering limu and other sea edibles, as mollusks, squid, sea urchins, and sea cucumbers or bêche de mer.

NATIVE METHODS OF PREPARING AND SERVING LIMUS FOR FOOD.

Immediately after gathering the limu it is very carefully washed, either in salt or fresh water, to remove all sand, mud, or clinging mollusks and crustaceans. The Hawaiian women are most particular about this cleaning process, so wash the seaweed through many waters, and look it over very carefully to remove every particle of grit or inedible limu that often becomes entangled with the edible varieties. (See limu cleaning in Plate IV, figure 2.)

A few varieties of limu can not be washed in fresh water without injuring the flavor and causing a very rapid decay, so that in a few hours it is entirely unfit for food. The following are the very perishable varieties that must be cleaned in salt water and eaten soon after preparation: Limu oolu, limu lipeepee, limu lepeahina (*Halymenia formosa*), limu moopuna-ka-lipoa (*Griffithsia* sp.?), and probably a few others not in general use.

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[a] The term "squid" is universally applied to the common octopus, *Octopus octopodia.*

After cleaning, the seaweed is always salted and usually broken, pounded, or chopped into small pieces, and usually it is eaten uncooked as a relish with poi, meats, or fish. Raw fish is never eaten without limu or some other relish, such as raw tomatoes, chili peppers, or onions.

The Hawaiians in the ancient times seldom cooked their limu, though it was occasionally placed in the imu or earthen pit with pig or dog and roasted or steamed. This was done when there was a famine or war and taro and sweet potatoes were scarce. Limu akiaki, limu huna, limu manauea, and limu uaualoli were all sometimes cooked in this way as a substitute for taro and sweet potatoes.

The Hawaiians of to-day do far more cooking than formerly, because they are not hampered for cooking utensils as their ancestors, who had no vessels that could be set over the fire. Water could only be heated by putting in hot stones, and boiling or stewing was almost impossible. Their only method of cooking meats or fish was in the primitive imu, or pit lined with stones and heated with a big fire. This when well heated was lined with banana and ti[a] leaves, then pigs, dogs, fish, taro, or sweet potatoes were placed on the ti leaves, covered well with ti and banana leaves, while over this was heaped earth. This was allowed to steam twelve hours or more before serving. Usually hot stones were placed in the pig to hurry the cooking, or if the pig was large it was cut into small pieces for each individual. These small pieces with a roll of taro leaves or some gelatinous limu were placed in ti leaves and tied in bundles, which were placed in the pit and roasted as described above. The limu when steamed in this way with meats becomes gelatinous and is flavored with the meat juices. It is considered very delicious by the natives, who always eat it with the roasted meat and sweet potatoes.

Very few poor Hawaiians have stoves or ovens, so that all their baking or roasting is still done in the primitive way. Their cooking is done over a fire in an old coal-oil tin out of doors, hence must be very simple. Meat is usually boiled or stewed in small quantities with taro leaves or limu. Whenever any Hawaiian gives a large dinner the pig and fish are roasted in the imu as in olden days. The following limus are often cooked with boiled meats or put into soups or gravies for thickening and flavoring, as well as with roast pig in the imu: Limu akiaki, limu uaualoli, limu loloa, limu lipeepee, limu kohu, limu lipoa, limu eleele, limu pahapaha, limu huna, limu manauea, limu aalaula, and limu kala. The tougher, more cartilaginous ones are boiled long enough for the gelatin to be softened or dissolved, as limu akiaki, limu huna, limu manauea, limu uaualoli, limu loloa, and limu lipeepee, while the others are only dropped into the hot soup or gravy just as it is about to be served.

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[a] *Cordyline terminalis*, found on the mountain sides on the edges of the forest. The leaves are used instead of paper for wrappers for food, and for plates, etc. The root is roasted and eaten and is also fermented into a kind of strong drink like rum.

Limu huna is especially prized for boiling with squid or octopus, though limu manauea and limu akiaki are often used as substitutes. These limus, when boiled with squid, produce a jelly of which the Hawaiians are very fond. Limu manauea is considered by native cooks especially fine when boiled with chicken, as it thickens the broth. Sometimes grated cocoanut and cocoanut milk are added to the chicken, forming a very delicious fricasse, which the writer has tested with very great appreciation. The writer has tried nearly all of these gelatinous limus with boiled beef and in beef or other soups, and finds them excellent. They are particularly palatable in vegetable soups, and are probably equally good in chicken or mutton broth, where the limu would make an excellent substitute for tapioca or sago, so often used by American cooks. Limu eleele, being a general favorite and so widely distributed, forms a part of every native feast. After being thoroughly soaked and washed in fresh water it is salted slightly and served uncooked, with poi and fish or meats. It is sometimes put into hot gravy or broth and in meat stews just before being served. It may be kept with a little salt about a week. Some natives allow it to pass through what they call a ripening process, which is as follows: The limu is soaked twenty-four hours or more in fresh water after being cleaned, when it begins to change color, becomes yellowish, slimy, and decomposes somewhat, developing a very rank odor. It is then said to be ripe and ready to eat. When sold in the market it is usually freshly prepared the day before, so is generally eaten without ripening or decomposing.

Limu aalaula, Limu kala, limu moopuna-ka-lipoa, and sometimes limu pahapaha pass through very much this same process of ripening before they are served by some of the Hawaiians in certain localities. Limu kala when ripened in this way is separated from the stems and floats, as only the leaves are eaten. Limu kala is more often eaten fresh and without any preparation whatever. Just as it is taken from the sea it is broken into convenient pieces and serves as a relish with raw fish or squid, which are frequently eaten on the beach as soon as they are taken out of the water and almost before they are dead.

The edible fresh-water algæ are often subjected to the ripening process described above. There are a number of these fine green algæ much alike in appearance called limu palawai, or lipalawai, limu nehe, and limu haulelani, which are usually found in the cool, swift mountain streams or pools. They are all the green threadlike forms of *Cladoph-*

ora nitida, *Spirogyra* sp. (?), *Hydrodictyon reticulatum*, *Pithophora affinis*, *P. polymorpha*, *Stigeoclonium amœnum*, *S.* sp. (?), and other species unidentified, probably Spirogyra and Cladophora. These fresh-water algæ are sometimes taken fresh from the stream and eaten with fresh-water shrimps or opai and a little salt. These fresh-water limus are also occasionally cooked with pig in the imu, or put into the gravy. Most of the fresh-water algæ are eaten by the natives living in the mountain valleys, as the people on the beach seem to prefer their own more accessible seaweeds.

There is a flowering plant found in fresh-water ponds that is eaten by the Hawaiians with great relish, especially with raw opai. This flowering plant (*Naias major*) is called limu kala-wai because it resembles slightly the limu kala from the sea. It is eaten raw with a little salt, much as water cress. It is considered particularly appetizing with raw fresh-water shrimps, opai, or crabs. It is often sold in the market during February and March, when it seems to be most abundant.

Limu lipoa is very often pounded and mixed with other seaweeds to give them its peculiar penetrating, spicy flavor and odor. It is frequently served with meats or put into the gravy or stews to give to them a peppery flavor, of which the Hawaiians are very fond. All Hawaiians like the odor and flavor of this alga, especially with raw fish. It is considered particularly delicious with raw flying fish, if simply broken and salted slightly. This seaweed has a very agreeable spicy taste and odor, and undoubtedly takes the place of sage and pepper in Hawaiian foods.

Limu kohu is always pounded well as it is being cleaned to free it from adhering bits of coral, and also so that it may be soaked more thoroughly to remove the disagreeable bitter flavor. It is soaked twenty-four hours or more in fresh water, to remove the bitter iodin flavor. It is then salted ready to be served as a relish or salad with meats, fish, and poi, or it is mixed with other seaweeds and put into hot gravy and meat stews, just as many other limus are eaten. Limu kohu has a rather pleasant flavor, though it is slightly bitter even after soaking twenty-four hours. It is always found in the market made into balls about the size of a large baseball and heaped upon large plates. It sells at 25 cents per ball and is always in great demand.

A very delicious condiment called inomona is made of the roasted kernel of the kukui[a] nut pounded fine with salt. Many Hawaiians also add a bit of chopped chili pepper and some limu, usually limu kohu, which is pounded very fine and then thoroughly mixed with the pounded kukui nuts and salt. This will keep for months in glass jars, and is excellent with bread and butter or cold meats. It resembles Russian caviare in flavor, especially when eaten with bread and butter. The Hawaiians serve this with poi, raw or cooked fish, or roast meats as a relish or condiment. Other limus as limu lipeepee or limu manauea are also sometimes used in making inomona, and if chili peppers can not be obtained, the large green peppers are cooked in ti leaves, then pounded and used instead. The dried gills of the squid roasted in ti leaves are also added by some Hawaiians.

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[a] The kukui tree or candlenut (*Aleurites mollucana*) grows abundantly in our mountain valleys and mountain sides, bearing oily nuts, which were strung on grass and burned for torches or candles in ancient times. The oil was extracted and burned in stone lamps. The nuts are edible if roasted.

Limu luau or limu lipahee, as it is called in Hawaii (*Porphyra leucosticta*), is prepared by washing in the usual way in fresh water. It is then salted a little and put into clear water, where it becomes slippery and colors the water a lovely violet color. Sometimes opihi, a kind of limpet or mollusk, is put in with the limu and salt and water and placed in bottles or jars. This is used as needed, for it keeps many weeks when placed in the weak brine with the limpets. The tender tips of limu pahapaha are sometimes prepared by rubbing and crushing between the fingers, and then it is mixed with small mollusks of a special kind and salt. The finely pounded limu uaualoli is sometimes mixed with salt and small limpets in very much the same way.

The soft parts, particularly the eggs and sperm, of several kinds of sea urchins are salted and mixed with limu uaualoli, limu kohu, or other pounded limus, and this mixture is served and always eaten raw for a relish or entré. In the same way loli (several species of holothurians, as sea cucumbers, bêche de mer, and others) are cut into small pieces and mixed with pounded limu, salt, and sometimes a little chili pepper is added and then served uncooked.

Limu lipahapaha is sometimes boiled with squid, just as limu huna, and forms a gelatinous mass when cold. Limu ekahakaha is sometimes simply pounded and mixed with limpets and sometimes it is cooked with the limpets and seasoned with chili peppers and salt.

Limu aalaula is often pounded very fine and mixed with pounded salted squid, while chili peppers may also be added if preferred. It is also sometimes pounded with other seaweeds to be eaten with poi and fish or meats.

Limu kala is sometimes broken into small pieces and soaked in fresh water until it turns dark and soft, then stuffed into salmon before it is roasted, or it is chopped with fish heads and salt. Again it is sometimes ripened by putting in water with a few mollusks called leho, salted slightly, and allowed to stand several days before eating. Limu kala is more often than any other limu eaten on the beach, without any preparation other than rinsing off the sand and breaking into convenient pieces for eating with raw fish or squid. It is also sometimes put into meat gravies or stews just as it is served.

Limus when eaten raw and crisp with a little salt, or with chopped chili peppers added, are very pleasant appetizers with meats or fish. The writer thinks that the Americans and Europeans would find them more palatable with the addition of vinegar or lemon and pepper, or possibly an oil dressing. They serve much the same purpose in the Hawaiian diet as our salads, and certain varieties certainly have a very pleasant saline flavor and crispness.

Sometimes various shellfish, as crabs, shrimps, small mollusks, and holothurians or sea cucumbers, are chopped into small pieces and then mixed with the pounded limu and salt and often bits of chili pepper are added to the mixture. This is served with poi, meats, or fish.

Certain seaweeds are always used with certain kinds of fish or mollusks, because their peculiar flavors are considered best when blended together. Shellfish and mollusks are usually eaten raw, and that is probably why chili peppers are usually added, just as with raw fish, to sharpen the flavor, which alone is rather insipid.

THE MOST POPULAR VARIETIES OF LIMUS.

The three limus which are most popular and in the most general use by natives on all the islands are limu eleele, limu kohu (Pl. V), and limu lipoa. None of the other limus are so widely distributed on all the islands nor found in sufficient quantities to be in such general use and favor, except limu pahapaha and limu kala. Neither of these is popular with many Hawaiians, so they are used but little, even though abundant on all the islands.

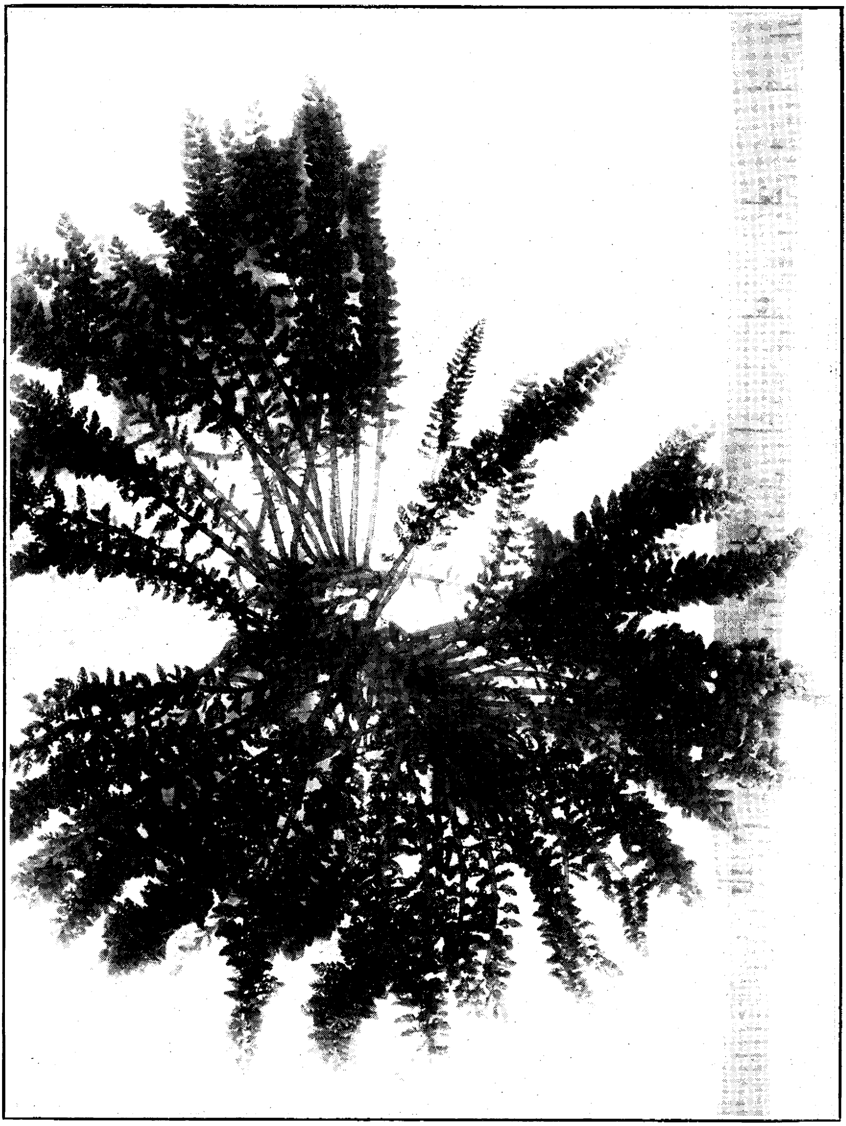
Next in favor are limu manauea (Pl. VI, fig. 1), limu huna (Pl. VI, fig. 2), and limu pakaeleawaa (Pl. VII, fig. 1), though the latter is native only on the islands of Hawaii and Maui. It was transplanted by certain chiefs to a few places on Oahu and Molokai. The writer was unable to find any specimens of this limu on Kauai or Niihau when collecting on these islands during the summer of 1905, yet several natives insisted that it occurred in Kauai.

Limu luau is considered a great delicacy in the few localities where it occurs, but it lasts so short a season, is so scarce, and so difficult to get that it is not very widely known. Only on northern Kauai, northern Maui, and northern Hawaii is it in use or in great favor, as it does not occur in other places, except a few scattered plants on Molokai and Oahu.

METHODS OF PRESERVING SEAWEEDS.

The Hawaiians usually preserve their seaweed, if only to be kept a few days or a week, by simply salting and tying closely in several layers of ti leaves and placing in a shady place. The ti leaves keep the seaweed from drying and also keep it crisp. The pounded seaweed is often stored in calabashes or glass jars after it is salted or put into weak brine.

PLATE V.



LIMU KOHU (ASPARAGOPSIS SANFORDIANA).

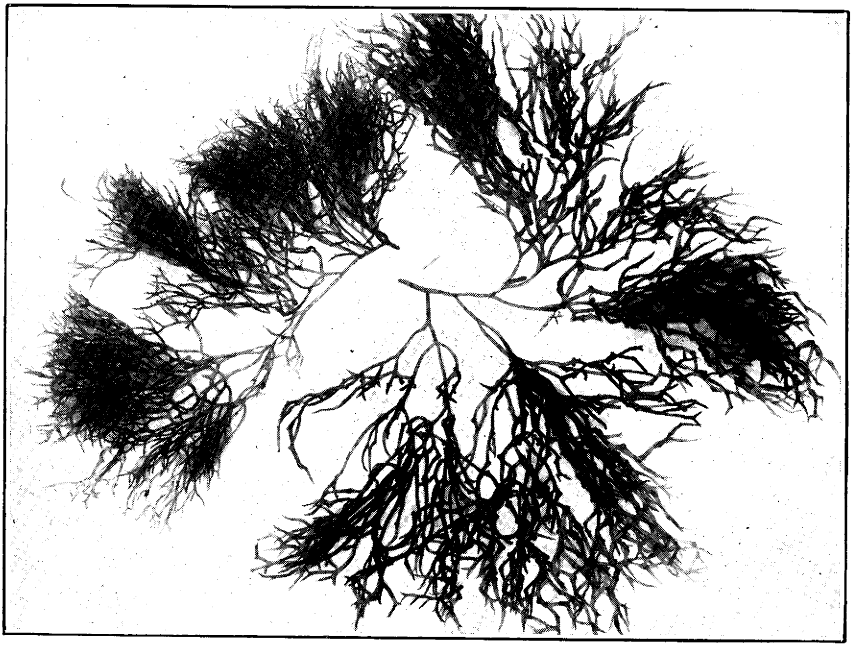


FIG. 1.—LIMU MANAUEA (GRACILARIA CORONOPIFOLIA).

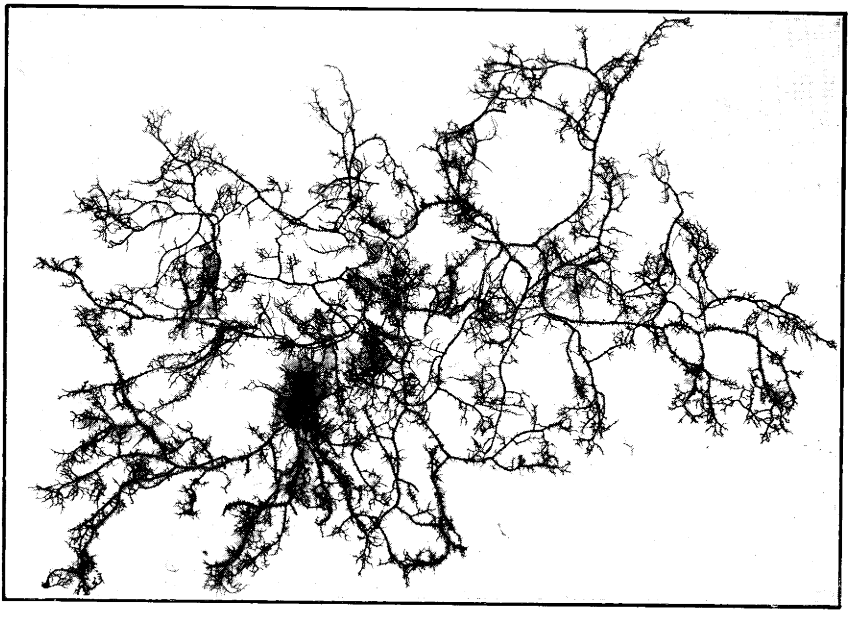


FIG. 2.—LIMU HUNA (HYPNEA SP.).

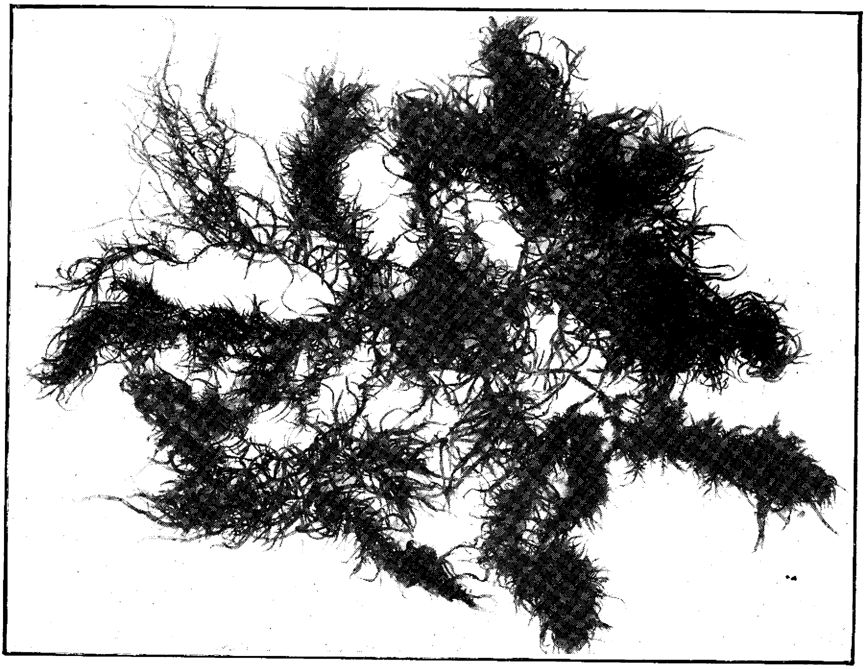


FIG. 1.—LIMU PAKAELEAWAA (GRATELOUPIA FILICINA).

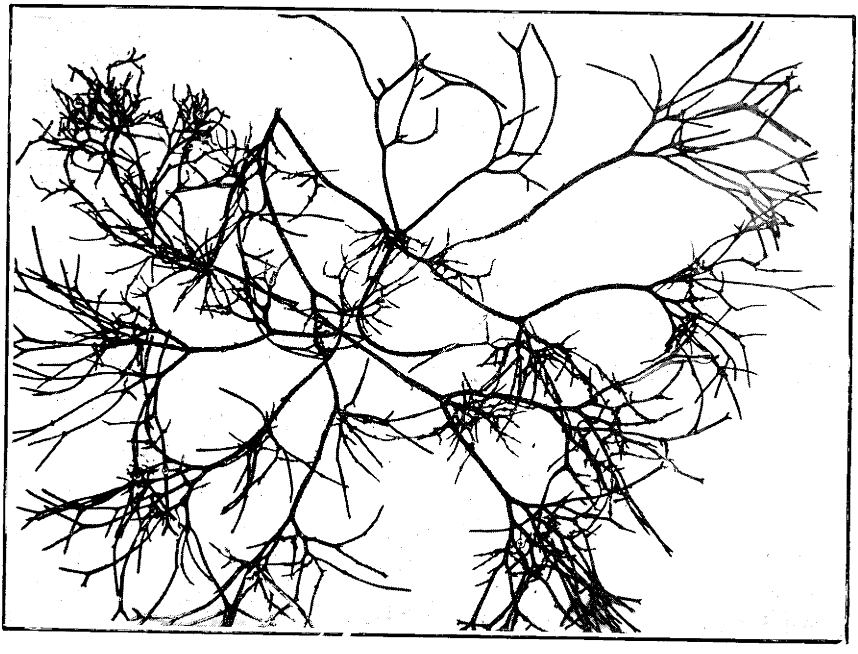


FIG. 2.—LIMU AKIAKI (AHNFELDTIA CONCINNA).

Limu kohu, limu pakaeleawaa, limu liopa, and limu luau will keep many months, or even a year, when thus preserved. Limu lipoa is not usually kept very long, not more than a few weeks. Most all the other limus in common use are only kept from one or two days to a week, depending upon the weather and the locality. If limu is placed on ice it keeps considerably longer.

Limu pahapaha and limu pakaeleawaa are occasionally kept indefinitely by simply drying without washing off the sea water. Hawaiians very seldom use this method of preserving the limu, as they seem to think that it would be spoiled if allowed to dry. But few Hawaiians seem to know that almost all the seaweeds on the Hawaiian coast can be dried without any perceptible injury either to color, flavor, or texture. The writer has tried almost every species of Hawaiian seaweeds, and with two or three exceptions it was impossible to tell the dried specimens from the fresh if they were first soaked an hour or two in salt water. If fresh water is used for soaking or washing seaweeds it often removes the coloring matter either of the fresh or dried limu. Therefore it is best to add as much salt as is found in normal sea water when washing or preparing seaweeds, either for food or for specimens.

THE LIMUS MOST ABUNDANT AND EASILY GATHERED.

Perhaps the limus most abundant and widely distributed over all the islands are the various kinds of limu kala, and next, perhaps, are several kinds of limu pahapaha, which are found on all the islands and in considerable quantity. Limu huna and limu manauea are very abundant on the islands of Molokai, Oahu, and Kauai, and especially on the leeward side and where there are low shallow beaches and wide coral reefs. Limu huna is scarce on Maui and not reported from Hawaii at all and was not observed there by the writer when collecting. Limu manauea is less abundant on Hawaii and Maui than on the other islands. Limu akiaki occurs in large quantities on the submerged black lava of Kauai, Oahu, and Hawaii, but is plentiful in a few localities on the other islands. At one time it was tabooed except for the chiefs. Limu loloa is most abundant on the islands of Kauai, Molokai, and Oahu, but is found in considerable quantities on the other islands. Most of the limu uaualoli is found chiefly on Maui and Molokai, but is rather scarce on Hawaii. Limu pakaeleawaa is only plentiful on the island of Hawaii on the southeast coast, but is found in limited quantities on Maui, Molokai, and Oahu, having been transplanted to the last two islands. Limu eleele is found in large quantities in the brackish water at the mouth of all the streams that are not too swift.

All the limus mentioned above are easily gathered except limu uaualoli, which grows on the stormy side of the islands on the most exposed rocks, so unless the weather is very calm it is rather difficult to secure in large quantities.

Limu oolu grows in shallow water near shore or farther out on the shallow sand-covered reefs where the water is quiet, hence is quite easily gathered, but it occurs in rather limited quantity in but a few places.

All the other limus are more difficult to gather and also occur in more limited quantities and in but few localities. This is especially true of limu luau, which is extremely difficult to collect and is very scarce. It grows only on the most exposed and slippery rocks, and disappears in a few days after the stormy weather subsides not to reappear until the next season immediately after the heavy winds. Therefore this much-prized limu is always most difficult to obtain even in very small quantities.

Limu kohu, which is so eagerly sought, grows usually far out on the exposed rocks or on coral reefs, where the breakers dash, so is rather difficult to get even in quiet weather and impossible in heavy storms. Occasionally, however, it grows on reefs less exposed and more accessible.

Limu lipoa is limited to certain localities, and occurs in rather small quantities. It grows in rather deep water, so usually can be gathered only by diving or swimming. It is found in small quantities on all these islands, and is a general favorite.

Limu huna and limu manauea are often drifted upon the beach by the heavy winds or high tides, and may be very easily gathered in boat loads by wading along the shallows at low tide and gathering up the drift on the shore and at the water's edge. It is especially abundant where there are very wide coral reefs under shallow water and a sandy bottom. There are tons and tons of these two limus on the south coast of Molokai, south and east Kauai, and almost all around Oahu, except off Kaena Point and in the harbor, where the water is too deep or muddy for seaweeds to thrive. Wherever there are shallows or reefs off Maui it is also plentiful, though not in such large quantities as the other islands mentioned, because of a less favorable coast.

Limu manauea and limu huna are most abundant in early spring and during the summer months, though both are found in considerable quantities all the year, as would naturally be expected in a tropical region.

Limu loloa can be secured in large quantities all the year round on Molokai, Oahu, Kauai, and Maui, but is not so abundant on Hawaii. It grows on the great lava rocks exposed to waves, so in heavy storms it is difficult to secure.

Limu akiaki (Pl. VII, fig. 2) may be obtained by boat loads all the year, if not too stormy, as it also grows on the great black lava rocks exposed usually to heavy surf. Sometimes it grows in quiet coves or behind the great lava rocks alongshore in less exposed places, but never in shallow water.

NATIVE METHODS OF CULTIVATING LIMUS.

The writer was much surprised to learn that a rude kind of cultivation of the much-prized limu kohu was practiced at Moloaa, on Kauai. Here limu kohu grows very luxuriantly over the entire reef, and is the finest in color and flavor found on this group of islands.

There is a small cove just beyond Moloaa Bay to the northward, which is partly protected from the heavy trade winds and southerly storms by bold, rocky bluffs or headlands. The coral reef extends from the shore out perhaps a half mile and beyond the headlands, so that the whole cove has rather shallow water. The coral rock, the usual haunt of the limu kohu, is in this place somewhat protected from storms, so the natives can gather this limu almost any time of the year, when the tide is low, without danger from heavy breakers.

The Hawaiians living at Moloaa gather limu kohu for the Honolulu market regularly, making a nice little income from its sale, as they furnish the larger share of the supply. It is here that these limu gatherers have attempted to increase their sales by caring for their seaweed to the extent of weeding out all the other algæ, and thus, no doubt, increasing the quality and quantity of limu kohu, which here is so much finer and more luxuriant than in any other place. This is the only place of which the writer has heard where the limu is actually weeded and cared for as a garden. There are, however, several places where a certain favorite limu has been transplanted from other islands and guarded carefully until it could get established. Limu pakaeleawaa was transplanted from Hawaii to Molokai by an old chief, who planted it on the inner edge of his fish pond, where it is now growing luxuriantly. This same limu has also been transplanted to the beach in front of the residence of ex-Queen Liliuokalani, near Diamond Head, and also in front of her Waikiki place. It is thriving in both places, so the writer has been told. This last summer, when collecting on the north side of Oahu, in Kaneohe Bay, the writer was much surprised to find limu pakaeleawaa growing luxuriantly on the rocks near shore. The native fishermen said that it had been planted there many years before by a chief, who brought it from Hawaii. In all these instances there is an attempt to aid nature, and so a crude kind of limu culture is practiced in Hawaii, though, of course, it is not so extensive or systematic as that in Japan. There may have been more attempts at cultivating or transplanting seaweeds by the natives of the past, for no doubt when a chief moved from one island to another he brought with him his best taro and yam plants for his lands; why not his favorite limus to his fish ponds or beach?

VALUE AND AMOUNT OF NATIVE SEAWEEDS SOLD IN HONOLULU.

It would be rather difficult to tell the exact amount or value of all the seaweed sold each year in Honolulu, but it is possible to make a fairly accurate estimate from the market inspector's report and the Chinese merchants' statements.

The inspector of the fish markets reports the annual sale of 4,800 pounds of limu, valued at about $2,500. It is sold almost exclusively to the Hawaiians or part Hawaiians. Of this total about 2,000 pounds is limu kohu, which is worth about $1,000 at retail. The remaining amount is about two-thirds to three-fourths limu eleele and limu oolu. All the rest are comparatively scarce or not so popular, so are only in the market occasionally during certain seasons of the year. Limu kohu is always in the market, while the other limus are usually found only on Saturdays and the day before holidays.

The following limus are found in the Honolulu fish market, either regularly or at intervals, according to the season or the weather: Limu kohu (*Asparagopsis sanfordiana*), limu eleele (*Enteromorpha prolifera*, *E. flexuosa*, *E. intestinalis*, *E. hopkirkii*, and *E. plumosa*), limu oolu (*Chondria tenuissima*), limu lipeepee or limu maneoneo (*Laurencia papillosa*, *L. pinnatifida*, *L. virgata*, *L. obtusata*), limu manauea (*Gracilaria coronopifolia*), limu lipoa (*Dictyota acutiloba* and *Haliseris plagiogramma*), limu kalawai (*Naias major*), and occasionally limu huna.

Usually these native limus are cleaned, pounded, and salted all ready for serving before they are offered for sale in small plates or saucers. These plates contain from a half pound to a pound of the limu, which sells at from 5 to 25 cents per plate, depending upon the kind. A few varieties like limu lipoa, limu lipeepee, limu manauea, limu huna, and limu kalawai, or fresh-water kala, are sold in loose handfuls, with no preparation except washing off the sand. Every native who buys a fish or a lobster also buys his plate or handful of limu.

Limu kohu is always pounded fine enough to be pressed into balls before it is packed with salt in tins or barrels to be shipped to Honolulu market. When retailed it is made into balls about the size of a large baseball and weighing about a pound. They always sell at 25 cents each, though the balls are smaller in stormy weather when limu kohu is scarce. All these limus are very moist, so they are always tied up neatly in fresh green ti leaves when purchased to prevent the water from leaking out upon the buyer's clothes. The ti leaves also keep the limu fresh and moist and never soak up the water as paper does if tied about something wet.

Nearly all the limu is sold in the market by native women, who have other Hawaiian delicacies, as sea urchins, roasted kukui nuts, crabs, cocoanut pudding, small cubes of raw beef liver, ready to serve with limu, etc.

The amount of limu sold in Honolulu does not of course include nearly all that is actually consumed either on these islands, on Oahu, or even in Honolulu, as every native family living on or near the beach gets its own supply of algæ fresh from the sea whenever it is desired.

VALUE OF SEAWEEDS IMPORTED BY ORIENTALS INTO HAWAII.

The Japanese and the Chinese of Hawaii use a large quantity of seaweed of various kinds, either prepared in various ways or simply roughly dried. The Orientals seldom use the Hawaiian algæ, as they prefer that cured and prepared in their own country. This is sold only in the Chinese or the Japanese grocery shops.

Most of this imported seaweed comes from Japan and is either kombu or wakame and its various preparations. The Japanese consular report for 1904 says the amount of seaweed sold to Hawaii and to the United States was as follows:

Japanese seaweed sold to Hawaii and the United States, 1904.

Seaweed from Japan.	Weight.	Value.
	Pounds.	
Rough-dried algæ sold to Hawaiian Islands	112,492.73	$1,587.15
Cut or prepared algæ sold to Hawaiian Islands	40,789.77	876.14
Algæ isinglass or kanten sold to Hawaiian Islands	1,751.61	470.72
Algæ isinglass or kanten sold to United States	61,588.31	15,152.30
Total	216,622.42	18,086.31

Nearly all the seaweed preparations described by Hugh M. Smith in his Report of the Japanese Seaweed Industry are sold here in Honolulu by the Japanese grocers to our Japanese population. The different seaweeds and their preparations vary in price from 5 to 30 cents per pound retail. The kanten costs about $1.50 or $1.65 per pound, and it is extremely light for its bulk. Amanori sells in small, thin sheets about 5 by 12 inches for 10 cents per dozen sheets. These sheets are almost as light as paper. Kombu and wakame are sold in the largest quantities, and are boiled to serve with rice, fish, and vegetables.

The Chinese import large quantities of seaweed each year, but there are no consular reports that give the amount or its value; so the following figures are taken from various estimates made by intelligent and responsible Chinese merchants who import this commodity. There are probably 70,000 to 80,000 pounds of seaweed, valued at from $10,000 to $12,000, imported and sold annually by the Chinese grocers of Honolulu.

The prices of these Chinese seaweeds vary from 10 or 15 cents per pound retail for che choy or kum choy (*Porphyra perforata* and *P. nereocystis*), 7 to 35 cents per pound for toi choy, hoy tai, and san choy (all *Laminaria* sp.), and 75 cents to $1.50 per pound for fat choy (*Nostoc commune flagelliforme*).

The most expensive varieties of seaweed are not sold in large quantities, and of course are purchased only by the most prosperous class of Chinese for feasts and holidays. Fat choy is used in very small quantities, as it is extremely light, swelling greatly in water when soaked or cooked, so that an ounce makes a considerable bulk when ready to serve. This is also true of most dried seaweeds, and especially of the common kombu, wakame, and che choy.

Che choy (*Porphyra perforata*) is imported from San Francisco and is a substitute for a Chinese alga called tsu choy (probably *Porphyra orbiculata* and *P. tenera*) which is greatly prized by the Chinese. It costs from 75 cents to $1 per pound when imported from China and keeps very poorly, often spoiling soon after its arrival; hence the use of the cheaper che choy from San Francisco. This retails here at 12 to 15 cents per pound, and is said to be almost as good as the Chinese variety. The tsu choy is imported only in small packages for the New Year feasts and sold to a few Chinese epicures.

One Chinese wholesale grocer said that he imported annually two or three tons of che choy, which costs from $600 to $700. He estimated that from 25 to 30 tons of this seaweed was imported yearly from San Francisco, costing from $6,000 to $7,000.

The Chinese use seaweed very much in the same way as the Hawaiians. They cook it in soups, stewed meats, or gravy, and also make it into pickles, preserves, or candies and other sweetmeats.

USE OF LIMUS FOR MEDICINE AND INCANTATIONS.

The writer has been unable to gather much data regarding the medicinal uses of limu, yet the few items collected are of considerable interest. Certain green fresh-water algæ, species of Spirogyra and Cladophora, are said to heal sore eyes if tied on as a poultice. Limu kala is pounded with salt and bound about bruises and cuts to relieve pain. Limu huna is sometimes boiled and the hot infusion given for stomach ache. Limu eleele is dried and put on boils, or it is sometimes used fresh and moist to poultice boils. Limu pahapaha is pounded and put on bruises. Lima luau is pounded to a pulp with salt and the juice is used to moisten bandages on cuts or bruises. Limu eleele and limu palawai are both pounded with salt and tied on cuts and bruises. Limu maneoneo is pounded with salt and the juice is put on cuts or bruises. A species of Centroceras, probably *C. clavulatum*, is pounded with salt and put on bruises and sores. An infusion of this same alga, when cooked, is given for a cathartic.

Limu kala is used by the kahunas or witch doctors in incantations to drive away sickness. The superstitious native when ill gathers limu kala, makes a lei for head or neck, eats some, says a prayer of penitence, promises to do better, then goes into the sea. He must not look back, speak, or beckon to anyone until he takes the limu lei, places it on head or neck, eats a bite of it, then throws the lei back into the sea, still looking out to sea and praying for forgiveness. This ceremony is said to cure if it is faithfully carried out.

It is believed that a most effective love potion is made from limu kalawai, or fresh-water limu kala as it is often called. The lovelorn maiden says over a magic spell learned from a kahuna, eats the limu kala, then gives some to the one whose love is desired. Straightway he adores her. Limu awikiwiki (*Gymnogongrus vermicularis*) was used also in love-making charms in ancient days, and was probably equally effective.

CHEMICAL ANALYSES AND COMPARATIVE FOOD VALUES OF SEAWEEDS.

The algæ when gathered are very succulent and contain a large amount of water. Considerable of this moisture is lost in the various methods of preparation for the table or for other uses. A number of specimens of Hawaiian algæ were analyzed by Mr. R. A. Duncan, food chemist of Hawaii, in connection with the writer's investigation of this class of plants, and the results are given in the table below, together with some similar analyses which have appeared in earlier publications of the Office of Experiment Stations and elsewhere. All the samples analyzed were air dry.

Composition of edible algæ.

[Air-dry material.]

	Water.	Protein.	Fat.	Carbohydrates.		Ash.
				Sugar, starch, etc.[a]	Crude fiber.	
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Irish moss (*Chondrus crispus*)[b]	18.8	9.4	....	55.4	2.2	14.2
Fat choy (*Nostoc commune flagelliforme*)[c]	10.58	20.93	1.19	55.73	4.07	7.50
Amanori or che choy (*Porphyra laciniata* or *vulgaris*)[c]	21.85	25.70	.17	37.68		14.60
Do.[d]	15.48	34.35	.65	38.83		10.69
Do.[d]	20.42	36.26	1.21	33.28		8.83
Do.[d]	16.40	35.63	.50	38.13		9.34
Do.[d]	14.58	32.44	.70	43.28		9.00
Do.[e]	13.98	33.75	1.30	41.22		9.75
Kombu or kelp (*Laminaria angustata*)[f]	22.82	5.49	1.52	46.93	4.55	18.69
Kombu or kelp (*Laminaria longissima*)[f]	25.94	6.72	1.73	31.90	6.42	27.29
Kombu or kelp (*Laminaria japonica*)[f]	22.97	4.96	1.59	47.49	5.83	17.16
Kombu or kelp (*Laminaria ochotensis*)[f]	23.99	6.65	.86	42.16	6.03	20.31
Kombu or kelp (*Laminaria religiosa*)[f]	22.75	4.72	.82	42.88	10.20	18.63
Kombu or kelp (*Laminaria fragilis*)[f]	23.10	4.03	.65	40.41	7.15	24.66
Kombu or kelp (*Laminaria* sp.)[e]	23.08	7.11	.87	47.70		21.24
Kombu or kelp (*Arthrothamnus bifidus*)[f]	24.43	5.82	.74	45.58	6.44	16.99
Kanten or seaweed gelatin[g]	22.80	11.71	....	62.05	....	3.44
Do.[h]	22.29	6.85	....	60.32	6.73	3.81
Awo-nori (*Enteromorpha compressa*)[i]	13.60	12.41	52.99		10.58	10.42
Awo-nori (*Enteromorpha linza*)[e]	13.53	19.35	1.73	46.18		19.21
Limu akiaki (*Ahnfeldtia concinna*)[j]	20.16	5.60	.07	54.96	2.66	16.55
Limu pahapaha (*Ulva fasciata* and *U. lactuca*)[j]	18.68	14.87	.04	50.65	.19	15.57
Limu manauea (*Gracilaria coronopifolia*)[j]	12.87	7.91	.05	58.41	2.98	17.78
Arame (*Ecklonia bicyclis*)[k]	13.17	8.99	....	45.70	7.40	24.74
Do.[e]	18.75	9.58	.46	51.63	9.79	9.79
Hijiki (*Cystophyllum fusiforme*)[k]	16.40	8.42	....	41.92	17.06	16.20
Do.[e]	15.74	11.37	.49	54.84		17.56
Ulopteryx pinnatifida[e]	18.92	11.61	.31	37.81		31.35
Ecklonia bicyclis, partially dried[l]	55.62	4.96	.40	13.60	19.16	6.26
Laminaria, partially dried[l]	52.96	4.11	1.44	29.68	5.25	6.56
Do.[l]	68.26	2.80	.48	19.50	3.29	5.67

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[a] Computed by difference except in a few cases which were actually determined.

[b] United States Dispensatory.

[c] U. S. Dept. Agr., Office of Experiment Stations Bul. 68, p. 47.

[d] Imperial Fisheries Bureau of Japan, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 160.

[e] Tahara, quoted in U. S. Dept. Agr., Office of Experiment Stations Bul. 159, p. 40.

[f] K. Oshima, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 153.

[g] O. Kellner, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 141.

[h] Imperial Fisheries Bureau of Japan, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 141.

[i] O. Kellner, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 164.

[j] R. A. Duncan, food chemist for the Territory of Hawaii.

[k] E. Kinch, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 163.

[l] Murai and Kasama, quoted in U. S. Dept. Agr., Office of Experiment Stations Bul. 159, p. 43.

For a proper comparison the fresh algæ should be compared with succulent green foods, like spinach and bananas, or such materials as poi or taro. If the air-dry materials are considered they should be compared with such articles as dried vegetables, crackers, meal, beans, cheese, dried beef, dried fish, etc. In the following table analyses are given of a number of common articles of food, and for comparison three of the more common limus are included, which have been calculated on a uniform water basis of 80 per cent:

Composition of marine algæ compared with other foods.

	Water.	Protein.	Fat.	Carbohydrates.	Ash.	Fuel value per pound.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*
Limu akiaki (*Ahnfeldtia concinna*)[a]	80.0	1.4	0.0	14.4	4.2	290
Limu pahapaha (*Ulva fasciata* and *U. lactuca*)[a]	80.0	3.7	.0	12.5	3.8	295
Limu manauea (*Gracilaria coronopifolia*)[a]	80.0	1.8	.0	14.1	4.1	290
Wheat bread[b]	35.3	9.2	1.3	53.1	1.1	1,185
Corn meal[b]	12.5	9.2	1.9	75.4	1.0	1,610
Crackers[c]	6.8	10.7	8.8	71.9	1.8	1,905
Taro[d]	67.5	1.9	.2	29.3	1.1	595
Poi[d]	83.0	.3	.6	15.8	.3	325
Potatoes[c]	78.3	2.2	.1	18.4	1.0	385
Sweet potatoes[c]	69.0	1.8	.7	27.4	1.1	570
Beans, Lima, shelled[b]	68.5	7.1	.7	22.0	1.7	555
Beans, dried[b]	12.6	22.5	1.8	59.6	3.5	1,560
Bananas[c]	75.3	1.3	.6	22.0	.8	460
Spinach[b]	92.3	2.1	.3	3.2	2.1	110
Beef, round[c]	67.8	20.9	10.6	....	1.1	835
Pork, shoulder[c]	51.2	13.3	34.2	....	.8	1,690
Codfish, salt[c]	53.5	25.4	.3	....	24.7	410
Beef, dried, salted, and smoked[c]	54.3	30.0	6.5	.4	9.1	840
Mullet[c]	74.9	19.5	4.6	....	1.2	555
Eggs, hen's[c]	73.7	13.4	10.5	....	1.0	720
Cheese, full cream[b]	34.2	25.9	33.7	2.4	3.8	1,875
Rice[b]	12.3	8.0	.3	79.0	.4	1,590

[a] Recalculated from figures given in preceding table to uniform water content.
[b] U. S. Dept. Agr., Office of Experiment Stations Circ. 46 (revised).
[c] U. S. Dept. Agr., Office of Experiment Stations Bul. 28 (revised).
[d] E. C. Shorey, Hawaii Experiment Station.

As will be seen by the data in the above tables, carbohydrates constitute the principal nutritive material present in algæ, though they contain considerable quantities of protein and relatively high proportions of ash. So far as can be learned little information is available regarding the character of the nitrogenous material present and the proportions of albumins, which have a high food value as compared with amids or other nitrogenous extractives. As a class the algæ differ very decidedly from the usual food materials in the character of the carbohydrates present, starch being usually replaced by such carbohydrates as mannit and substances which yield on hydrolysis various galactoses, mannose, glucose, pentose, etc.[a]

Judged by chemical composition the air-dry algæ compare favorably with other common food materials, particularly those of vegetable origin. It has been commonly supposed that the Irish moss, so much used in invalid dietetics, and other algæ and food made from them were very thoroughly assimilated, but recent experiments carried on by T. Saiki, at Sheffield Scientific School, Yale University, indicate that this is not the case, at least with respect to the carbohydrate constituents. That they are wholesome and are palatable additions to the diet in regions where they are eaten in quantity is well established, and it seems fair to say that they occupy much the same place in the diet as other common foods, particularly green vegetables. In order that digestion should be normally accomplished foods should be bulky, and in this respect the marine algæ would certainly prove useful. Mineral matters are needed for the formation of bones, teeth, and other tissues, and to fulfill other physiological functions. The algæ are rich in phosphates, chlorids, bromids, iodids, etc., and it seems probable that the mineral matter which they supply must be of importance to the body. As Saiki points out, the algæ gelatins are of much importance in counteracting constipation.

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[a] See summary of data in U. S. Dept. Agr., Office of Experiment Stations Bul. 159, p. 34.

AMOUNT OF GELATIN OR GLUE FOUND IN HAWAIIAN ALGÆ.

The writer made some rather crude experiments to test the various common limus of Hawaii for the amount of gelatin available by ordinary boiling. The most satisfactory results were obtained from the following varieties: Limu huna, limu manauea, limu akiaki, limu kohu, limu loloa, and limu pakaeleawaa. Some others were tried, but they contained very little gelatin or were too strong in flavor to make gelatin for foods. The limu loloa made a very dark gelatin, with a rather strong flavor, so would be more valuable for making mucilage than for gelatin. In making these experiments to extract the gelatin only a small coal-oil stove and a few tin pails were available for boiling the algæ. The seaweed was carefully washed and cleaned, then boiled in clear water from 1 to 3 hours. When it seemed well softened or dissolved, it was passed through a coffee strainer, then through coarse linen doubled. It came through clear, and soon stiffened on exposure to the wind and sun. It was all dried in clear, stiff, crisp sheets on plates in a sunny window. It looked as clear and fine in quality as the best gelatins of the market.

The time of cooking, the amount of gelatin obtained, as well as the quality, varied with the kind of seaweed used. Limu manauea makes the finest, clearest gelatin, and limu akiaki ranks next, limu huna third in quality, while limu pakaeleawaa makes the poorest and smallest quantity. Limu manauea requires the least cooking, and limu huna is next, while limu loloa makes the darkest colored and strongest flavored gelatin. It would make an excellent glue, because it is very sticky, but dries hard as glue should.

Roughly estimated, these seaweeds yield 75 to 80 per cent of their dry weight of gelatin or glue. The writer had no means of carefully weighing the materials to get the exact proportions of seaweed and the glue or gelatin obtained in order to make accurate estimates of their ratios. All the seaweeds occuring on Hawaii in large quantities were tested for gelatin with the above results. Limu uaualoli probably contains a considerable amount of gelatin, but is difficult to gather and can only be secured with some difficulty, and only in very moderate quantities on the north side of Maui, Molokai, Oahu, and Kauai. It is possible that some of the species of Laurencia as limu lipeepee and limu maneoneo might yield some gelatin, but they do not occur in large enough quantities to be of importance in this consideration.

The writer tried using some of this seaweed gelatin as mucilage for pasting on labels and pictures, etc., and found it just as satisfactory as ordinary library paste. It left no shiny mark on the edges. If kept from fermenting by some preservative it would undoubtedly be just as useful as any other mucilage.

HAWAIIAN LIMUS FOR MAKING AGAR AGAR FOR CULTURE MEDIA.

Two small jars of the clearest, best gelatin made from limu manauea and limu huna were taken to the laboratory of Dr. N. A. Cobb, plant pathologist at the Hawaiian Sugar Planters' Experiment Station, to be tested as culture media. He reported them to be quite satisfactory for cultures of various fungus diseases. No doubt if this gelatin were mixed with beef tea, milk, or other suitable foods it would make just as satisfactory a medium for the culture of the bacteria. If we could produce our own agar agar in the United States it would of course save importing it from abroad. Most of the agar agar used in the laboratories of the United States and Europe is made from the algæ of Japan and Ceylon or Java. It is prepared partly in Japan, but the best quality is sent to Germany to be manufactured. We have tons of gelatinous algæ here in Hawaii that would make the best quality of agar agar if we chose to manufacture it ready for the bacteriologist.

FURTHER UTILIZATION OF HAWAIIAN SEAWEEDS FOR FOOD, GELATIN, FARINA, GLUE, AND MUCILAGE.

It is not probable that raw seaweed prepared in the usual Hawaiian style would ever be generally popular with the American or European, who naturally prefers his own salads and relishes to which he is accustomed. Even those having the most pleasant saline flavor and crispness, as limu kohu, limu manauea, limu huna, and limu pahapaha, or limu lipoa, with its peculiar pleasant spiciness have in addition a slight flavor that suggests the sea, to which many people object. It is only after tasting several times that many people come to really like the marine flavor, common to all raw seaweeds. All the others that the writer has tasted, except those mentioned above, have a much stronger flavor, which is sometimes slightly bitter or suggests iodin, or, again, it is slightly fishy, so that it would not appeal to the average American palate.

Many of the seaweeds, when cooked in soups, gravies, or with meats or made into jellies, are entirely free from this disagreeable or peculiar flavor. If cooked too long, or too large a quantity is used in the soups or jellies, the flavor is apt to be strong, but if used in smaller quantities it is very delicate and pleasant. The writer has carefully tested a number of species, cooking them in a variety of combinations. They seem to be equally palatable when used either fresh or dried. The bleached seaweeds of course make the best appearing jelly and blancmange, and look best in the soups and stews.

The most attractive and delicately flavored coffee, fruit, or other jellies and blancmange was made by the writer from the four gelatinous limus mentioned above. They were equal in every way to jellies made from the best gelatins in the market, and in some ways seemed superior in flavor. The blancmange could not be distinguished from that made with Irish moss farina or with the whole Irish moss.

No doubt these native limus which occur in large quantities could be collected and bleached on the sand or rocks by the natives, and when dry and clean ground into farina or made into gelatin as good as any in the market. The farina made from limu huna, limu manauea, limu akiaki, and limu pakaeleawaa would be excellent for thickening soups, stews, and gravies or puddings in the same way as tapioca, sago, or Irish moss farina. When once the public became acquainted with these preparations without doubt they would become popular. A careful, experienced manufacturer might, it would seem, start a new industry here in Hawaii or on the California coast by utilizing the tons and tons of edible and gelatinous algæ in making gelatin or glue, such as that made in Japan, or farina, as on the coast of New England. There is no reason why Hawaiian species could not be made into as good gelatin and glue as the Japanese or Ceylon algæ. If scientific methods were used in its preparation, and labor was reasonable, we ought to be able to make our algæ as profitable as that of Japan. The many poor Hawaiians living along the beaches, who have no fertile land to cultivate and are only skilled in fishing, swimming, and rowing, could engage in collecting algæ for such a factory. The women and children could help in this industry and all could stay at home together. They would need no tools and no capital or no training for this work. A few simple instructions about cleaning, drying, and bleaching would be sufficient, for the natives know the haunt of every edible limu. A very cheap mill would do for grinding the limu into meal or farina, which would need to be boxed and labeled attractively. The gelatin factory would require more machinery and more capital. It may be that if no factory should be started here our Hawaiians might collect, dry, and bleach their limus and ship them to the coast in bags ready to manufacture, and still make it a profitable industry.

METHODS OF PREPARING JELLIES, BLANCMANGE, SOUPS, ETC.

Coffee jelly and other similar jellies or gelatin desserts are prepared in the same manner as when ordinary gelatin is used, except that the gelatin must first be extracted from the algæ as described above in gelatin preparations. The clear, strained gelatin is then sweetened and flavored with fruit juice, coffee, etc., and placed in a mold to stiffen. It is then served with sweetened and flavored cream, just as with all gelatin jellies. The amount of dried seaweed needed for a pint of jelly varies from 1 to 4 ounces, depending upon the variety of algæ and the stiffness desired in the jelly. The time of cooking also varies with the algæ, and is from one to two hours.

Blancmange is made just as with Irish moss, by cooking the algæ slowly in sweet milk and then straining through a bag. After it is sweetened it is placed in the mold on ice to cool and served with cream sweetened and flavored to taste.

The same limus used in making gelatin are of course used for jellies, blancmange, and in meats and soups. Limu manauea makes the most delicately flavored desserts, though limu huna, limu akiaki, and limu pakaeleawaa are almost as good. Limu kohu is also a pleasant addition to soups or stews if used sparingly, an ounce or two to a kettleful of soup.

COMPARISON OF HAWAIIAN AND JAPANESE SPECIES OF ECONOMIC ALGÆ.

Though Hawaii is a group of recent volcanic islands in mid-ocean, it has a rather varied marine flora along the coasts. There are a hundred and ten or fifteen different species found on these islands. About seventy of these are used for food by some of the Hawaiians. From forty-five to fifty species are in general use for food by most of the Hawaiians on the different islands where they grow.

Japan, being composed of older continental islands, would naturally be expected to have a richer seaweed flora (and probably it has), but Mr. Smith[a] reports a much smaller number of edible seaweeds from those islands than we have in Hawaii. He reports but 35 species that are eaten by the Japanese and 10 others valuable for making glue, gelatin, iodin, fertilizers, etc.

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[a] H. M. Smith, Seaweed Industries of Japan. Bul. [U. S.] Bureau of Fisheries, 24 (1904).

Not all of these 70 seaweeds eaten by the Hawaiians would be agreeable to the palate of the average American. Probably not more than 8 or 10 out of the 70 would be eaten either by the American or the European, and some of these 10 only occur in limited quantity and only in a few localities. There may, of course, be a few seaweeds here in Hawaii that will prove to be valuable for fertilizers, iodin, or gelatin that have not yet been tested, as the Sargassums.

Probably none of our Hawaiian seaweeds occur in such large quantities as those in Japan, since our coast is much less extensive and many of our islands have bold, precipitous coasts, with very deep water coming up close to the shore on one or two sides. Algæ grow most abundantly in the shallower waters near the coast, and hence the more coral reefs and the more extensive shallows the greater variety and quantity of seaweed. It is, of course, more easily collected on shallow rocky coasts or in coves and bays protected by wide coral reefs, while it is always most plentiful on the coral rocks in these shallows. The tougher, more leathery varieties thrive in the more exposed places and find secure anchorage on the black lava rocks or basalt, as well as on the softer vesiculate lava, which is usually covered with algæ of various kinds, different from that growing on the coral.

While Hawaii is within the tropic zone and probably considerably warmer than Japan, yet she has some of the same species of economic algæ that grow on her coasts. Hawaii produces eight or nine species of Gelidium, while one is the same species (*Gelidium corneum*) which is found so abundantly in Japan and is used in the manufacture of seaweed gelatin. Our species of Gelidium are undoubtedly as gelatinous as the Japanese species, but they are not nearly so plentiful. We also have *Gracilaria confervoides* and *G. coronopifolia*, which are very common on the coasts of Japan. *Gracilaria coronopifolia* is particularly rich in gelatin of the best quality suitable for food, and it also occurs in considerable quantities on all the islands but Hawaii. Our *P. leucosticta* is somewhat similar to the two Porphyras of Japan used in making amanori, but is too rare and too difficult to collect to be of any economic importance here on Hawaii. We also have two edible species of Codium, while Japan has three edible species, but different from ours. Our edible *Grateloupia filicina* is the same as the one used in Japan, though they have two other edible species of Grateloupia. We have two of the three Japanese species of Enteromorpha, besides three or four more edible species. There are two edible species of Gymnogongrus reported from Japan, and we have the same number here, though different species. Of our three edible Ulvas, one is the same, one a variety, and the other is a nearly related species to those found in Japan. We have three or four species of edible

Sargassum, while Japan has only one species of Sargassum, which is used for making iodin.

The Japanese waters are rich in kelps, laminarias, alaria, ecklonia, and other genera of colder waters, but Hawaii has none, nor has she any Chondrus or Gloiopeltis, both of which thrive best in the North Pacific along the coasts of Japan and the United States. The kombu and wakome preparations of Japan are all made from Laminaria and related genera in the kelp group.

It will be seen from the above comparison of genera and species that there is some resemblance between the seaweeds of Japan and Hawaii. Our waters being warmer we naturally have more tropical species and no kelps. Yet quite a number of genera and several species are exactly the same. This would indicate either that these species flourish under widely different temperatures and conditions, or that our water is not so much warmer as the difference of latitude would suggest. Japan has the volcanic rock and the black lava just as we have here, but probably no coral reefs for the algæ.

POSSIBILITY OF CULTIVATING NATIVE, JAPANESE, JAVA, OR CEYLON ALGÆ IN FAVORABLE LOCALITIES ON THE HAWAIIAN OR AMERICAN COAST.

As previously mentioned, the Hawaiians have attempted a rude method of cultivating and transplanting their favorite algæ from one island to another. In moving from island to island the chiefs carried their favorite limu pakaeleawaa from Hawaii to Oahu and to Molokai. It was transplanted carefully along protected beaches or on the inner side of old fish ponds, where it still thrives. The writer found this alga growing only in one place on Molokai, and was told by the natives that it had been planted by a chief in his fish pond. In the same manner it has been planted on Oahu in several places and is thriving. Limu is weeded and cared for on the island of Kauai in order to increase the quantity and quality.

If these crude methods of culture succeed and the natives can establish an alga in a new place successfully, why should not more careful scientific means be very successful if the most desirable varieties of Hawaiian algæ were planted in the most favorable localities on each island?

Perhaps some of the most valuable Japanese algæ could be introduced on the coast of Hawaii and be successfully established. It is possible, too, that certain species of algæ growing on the coasts of Ceylon and Java could also be just as readily transplanted to our islands, because the temperature of the sea is about the same, especially off the coast of Hawaii. Much of the agar-agar of commerce is prepared from the gelatin obtained from seaweeds from Java and Ceylon. This very important requirement of every bacteriological laboratory might be produced here in Hawaii just as well as in Japan or the East Indies, providing, of course, that our own algæ proves as rich in gelatin or if the Japanese and East Indian seaweeds can be successfully introduced and cultivated here. Some experiments along this line might be very valuable, and they would certainly be very interesting. There are many of our rocks and reefs quite thinly covered or nearly barren of seaweeds, and these might be favorable places to establish new varieties, either from other islands or from Japan and the East Indies.

GENERAL SUMMARY OF THE POSSIBILITIES OF THE SEAWEED INDUSTRY.

If the seaweed industry of Japan is the source of an annual income of $2,000,000, it seems possible that our edible Hawaiian algæ might be available for building up a similar industry of considerable value. The coast line of Hawaii is much less extensive and the amount of seaweed of course very much less, yet there is enough material to supply large factories for making gelatin, glue, farina, or other products. If in addition to the present natural sources of seaweed new localities be successfully planted, either with native, Japanese, or other valuable foreign varieties, a still larger supply of algæ would be available for manufacturing. It would of course take some capital, business judgment, and knowledge of the seaweeds and their manufacture to successfully establish such an industry here or on the coast of the United States. If it is so profitable in Japan, why should it not be profitable here, if properly handled? There are enough Japanese laborers here who know all the methods of preparing algæ to suit the Oriental palate, and these could be employed to do that part of the work in the factory, while the Hawaiians, who love the water and are such expert swimmers and boatmen, could be employed to collect the crude algæ from the sea and bring it to the factory. This would bring employment to the untrained Hawaiians and furnish them with a means of living while they remained at home. The women and children could also help with this work of gathering and drying or bleaching the seaweed for the manufacturer. Some industry of this kind only will bring relief to the mass of the Hawaiians, who are unskilled and undisciplined, so are unable to compete with either the Orientals or Europeans in any branch of labor. The Japanese have driven them out of fishing, at which they are most skillful, because they will not be strenuous or regular enough to furnish the market with fish. Small farming is not practicable for the Hawaiian under present conditions, because it requires more capital, skill, and intelligence than the present Hawaiian possesses. Perhaps in two or three more generations the Hawaiian will acquire the skill, the capital, and the disposition to enter agricultural pursuits gladly. In the meantime poverty and distress are the lot of a large class of landless Hawaiians living along our coast. If the tons of algæ wasting on our shores could be utilized for gelatin, glue, farina, etc., it would bring some relief to this class, as well as add to the general wealth and prosperity of these islands and to the United States.

The gelatins and glues imported from Japan could be made in the United States just as cheaply, perhaps. Modern methods scientifically applied and machinery would reduce the manufacturing expenses to a minimum. A new source of food for our American people here and in the United States would add also to our national wealth. Further experiments and analyses should be made by the Government to test the nutritive value of our algæ and to find the best methods of securing the greatest amount of gelatin from each variety. Enough has already been done to suggest the future value of our economic algæ if properly utilized.

List of edible algæ of Hawaiian Islands.

Scientific names.	Native names.
Ahnfeldtia concinna J. Agh	Limu akiaki, or limus eleau. [a]
Asparagopsis sanfordiana Harv	Limu kohu, limu lipaakai, [b] limu lipehu, limu koko.
Amansia glomerata Ag	Limu lipepeiao, [c] or limu pepeiao.
Centroceras clavulatum (Agh.), Mont	Limu huluilio, limu hulu, or limu hulu wawae-iole.
Chætomorpha antennina (Bory.), Kuetz	Limu huluilio, [d] limu ilio, or limu manu.
Champia compressa, Harv	Limu oolu.
Chnoospora fastigata pacifica, J. Ag	Limu wawahiwaa, or limu kaupau.
Chondria tenuissima intermedia	Limu oolu.
Chylocladia rigens?	Limu akuila, or limu kihe.
Cladophora nitida, Kuetz	Limu huluilio.
Codium muelleri, Kuetzing	Limu aallaula, [e] limu wawaeiole, or limu wawaimoa.
Codium adhærens (Cabr.), Agh	Limu aalaula.
Codium tomentosum (Huds.), Stackh	Do.
Dictyota acutiloba distorta	Limu alani, [f] or false lipoa.
Dictyota dichotoma	Do.
Ectocarpus indicus?	Limu akaakoa, or limu huluilio.
Ectocarpus sp.?	Do.
Enteromorpha flexuosa (Wulf.), Ag	Limu eleele, or limu pipilani. [g]

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[a] Many of the limus have different local names, or each island or adjoining islands has its own name. Limu eleau is used on Maui only.

[b] This limu is usually called limu kohu, except on Maui, Molokai, and Kauai. It is often called limu lipaakai and sometimes limu lipehu. Limu koko is a corruption of kohu.

[c] Different forms of the same name on Hawaii, not widely used, local.

[d] Not widely used; only local on several islands, chiefly on Hawaii and Maui, and this name is applied to several species slightly resembling each other. It means dog's hair.

[e] The last two names found in use in some places on Hawaii, not common.

[f] This is generally called limu alani, but sometimes called false limu lipoa, which it resembles slightly. It is eaten but seldom, as it is bitter.

[g] On Maui it is sometimes called limu pipilani. Limu eleele is the name for most all the Enteromorphas of these islands.

Scientific names.	Native names.
Enteromorpha hopkirkii	Limu eleele, or limu pipilani.[a]
Enteromorpha intestinalis (L.), Link	Do.
Enteromorpha linza (L.), J. Ag	Do.
Enteromorpha plumosa, Kuetzing	Do.
Enteromorpha prolifera tubulosa, Kg	Do.
Enteromorpha prolifera (Muell.), J. Ag	Do.
Gelidium attenuatum?	Limu loloa.
Gelidium corneum var.? (Huds.) Lamour	Do.
Gelidium filicinum?	Limu loloa or limu ekahakaha.
Gelidium latifolium? Born	Limu loloa.
Gelidium micropterum?	Do.[b]
Gelidium pulvinatum?	Do.
Gelidium pusillum?	Do.
Gelidium sp.?	Limu kekuwelu or limu kuwelu.
Gracilaria coronopifolia, J. Ag	Limu manauea.
Grateloupia filicina (Wulf.), Agh	Limu pakaeleawaa or limu[b] huluhulu-waena.
Griffithsia sp.?	L. moopuna, limu ka-lipoa,[c] or limu aupupu.
Gymnogongrus vermicularis americana, J. Ag. *Gymnogongrus diciplinalis* (Bory.), J. Ag.	Limu uaualoli.[d] Limu ekahaekaha. Limu koeleele or koele. Limu awikiwiki. Limu nei.
Haliseris pardalis[e]	Limu lipoa.
Haliseris plagiogramma, Mont	Do.
Halymenia formosa	Limu lepeahina (very rare).
Hydrodictyon reticulatum (Linn.) Lagerh	Limu palawai.
Hypnea nidifica, J. Ag	Limu huna.
Hypnea armata	Do.
Laurencia papillosa (Forst.), Grev	Limu maneoneo[f] or limu lipeepee.
Laurencia pinnatifida (Gmel.), Lamour	L. maneoneo, limu olipeepee, or limu lipee.
Laurencia pinnatifida osmunda	Limu lipeepee or lipee.
Laurencia perforata	Do.
Laurencia obtusata	Do.
Laurencia virgata (Ag.), J. Ag	Do.
Laurencia sp.?	Limu maneoneo or limu lipuupuu.
Liagora decussata	Limu puaki.
Nais major, All	Limu kala-wai.[g]

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[a] On Maui it is sometimes called limu pipilani. Limu eleele is the name for most all the Enteromorphas of these islands.

[b] This name is in very general use on Hawaii and Maui, but both names are common on Oahu.

[c] This alga is considered a delicacy on Maui and southern Hawaii, but is very scarce and spoils very soon, so have not been able to secure enough to identify the species.

[d] This limu is usually called limu uaualoli, but the other names are used in certain localities.

[e] This is very rare, only washed ashore occasionally, but resembles the other limu lipoa, hence the name.

[f] The several species of Laurencia are generally called limu maneoneo, if coarse and short, and limu lipeepee if finer and longer. Limu lipee is an abbreviation, while limu lipuupuu has only local use in places on Hawaii and Maui.

[g] This is not an alga, but a flowering plant sold in the market as a limu, probably because it grows in fresh water and resembles the common limu kala from the sea.

Scientific names.	Native names.
Nitophyllum?	Limu haula.[a]
Pithophora affinis? Nordst	Limu palawai[b] or limu lipalawai.
Pithophora polymorpha	Do.
Polyopes?	Limu luau.[c]
Polysiphonia mollis	Limu pualu[d] or limu hawane.
Porphyra leucosticta, Thurst	Limu luau or limu lipahee.[e]
Pterocladia capillacea (Gmel.), Bornet	Limu loloa.[f]
Sargassum echinocarpum, J. Ag	Limu kala.
Sargassum cymosum, Ag	Do.
Sargassum polyphyllum. J. Ag	Do.
Spiridia spinella	Limu hulupuaa.[g]
Spirogyra sp. (probably several)[h]	Limu palawai, limu nehe, and limu polao.
Stigeoclonium amœnum, Kg	Limu huluilio.[i]
Stigeoclonium sp?	Limu palawai or limu lipalawai.
Strebdocladia?	Limu hawane.[h]
Ulva fasciata,[j] Delile	Limu pahapaha or limu palahaloha.
Ulva lactuca rigida (Agh.) Le Jolis	Limu lipahapaha.
Ulva lactuca lacinata (Wulf.) J. Ag	Limu lipalahalaha, limu pakaea.
Valonia utricularis	Limu lipuupuu.

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[a] Very rare, only one small specimen obtained from a native on Maui.

[b] Most all the edible green fresh-water algæ are called lipalawai or polawaie, and there are perhaps a half dozen species in the mountain streams that are known by these names.

[c] A single small specimen sent by native on Maui, similar to Porphyra.

[d] Used by but few Hawaiians for food; not popular.

[e] Reported only from two islands and scarce; called limu luau on Kauai and limu lipahu on Hawaii.

[f] This species often called limu loloa on Maui and Kauai.

[g] Not in general use, but eaten in the southern part of Hawaii.

[h] Imperfect and immature specimens, so could not be positively identified.

[i] This grows in brackish water pools by the sea and is eaten by only a few Hawaiians.

[j] These three species seem to be indistinguishable by the natives, and the different islands and localities have various forms of the name, but limu pakaea is only in use on Hawaii.

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Issued May 26, 1908.

HAWAII AGRICULTURAL EXPERIMENT STATION,

JARED G. SMITH, SPECIAL AGENT IN CHARGE.

ANNUAL REPORT

OF THE

HAWAII AGRICULTURAL EXPERIMENT STATION

FOR

1907.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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HAWAII AGRICULTURAL EXPERIMENT STATION.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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JARED G. SMITH, *Special Agent in Charge.*
D. L. VAN DINE, *Entomologist.*
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F. G. KRAUSS, *In Charge of Rice Investigations.*
Q. Q. BRADFORD, *Assistant in Rubber Investigations.*

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LETTER OF TRANSMITTAL.

Hawaii Agricultural Experiment Station,
Honolulu, Hawaii, February 15, 1908.

Sir: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year 1907.

Respectfully,

Jared G. Smith,
Special Agent in Charge.

Dr. A. C. True,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. True, *Director.*

Publication authorized.
James Wilson,
Secretary of Agriculture.

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ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1907.

SUMMARY OF INVESTIGATIONS.

By JARED G. SMITH, *Special Agent in Charge.*

The routine office, library, and laboratory work continued throughout the year on much the same lines as during the previous period of the station's existence. Building operations were confined to repairs to the residences on the station, the erection of an additional stable, and the enlargement of the stable capacity of the main barn where the work animals are cared for.

Congress having appropriated $5,000 for the installation of a water system, the plans which had previously been approved by the Secretary of Agriculture were carried out. A corrugated galvanized-iron roof about 200 feet square was constructed on Tantalus, at an elevation of about 1,200 feet. The iron was laid on purlins of 2 by 6 inch northwestern lumber, spiked to the tops of 5-inch split redwood fence posts, which had been set in the ground to a depth of about 2½ feet. This roofing conformed to the slope of the hillside, the purlins being nailed to the posts, so that when the tops of the latter were sawed they formed successive planes. At the lower edge of this roof a 2-foot gutter leads the water into a 30,000-gallon redwood tank. A 1-inch galvanized pipe leads the water from this 30,000-gallon tank down along the ridge into a 60,000-gallon tank, located immediately above residence No. 2, at an elevation of about 475 feet above sea level. Direct connections will be made from this tank to residences Nos. 1, 2, and 3. Another 60,000-gallon tank has been placed at the upper corner of the lower experimental fields, at an elevation of about 250 feet. Over 1 mile of piping has been laid to conduct water from this lower tank to the experimental plats. The materials for the construction of this water system, including two 60,000-gallon tanks and one 30,000-gallon tank, 12,000 feet of 1-inch pipe, 500 feet of 2-inch pipe, 400 feet of ¾-inch pipe, together with cement, dimension timbers for foundations, nails, roofing screws, pipe fittings, etc., cost $4,006.14. The plant was installed by day labor at a cost for labor and supervision of $993.75, leaving an unexpended balance of this appropriation of 11 cents.

Through delays in the delivery of materials on the part of some of the contractors this water system was not completed until after the end of the rainy season. Nevertheless, the tanks have been kept full practically all of the time, as hardly a day passes when there are not some showers at the elevation where the roof is placed. With an average rainfall amounting to about 120 inches per annum this water system will yield the station 1,250,000 gallons of water, and we now have a storage capacity of 210,000 gallons. This guarantees fire protection to station residences and office buildings, and insures a water supply for the experimental plats during the driest and hottest months of the summer, a period during which in previous years there has always been a shortage in the city water supply.

By using station labor under the immediate supervision of the director this plant was installed at a cost of less than 25 per cent of the cost of the materials used.

In July, 1906, two Wardian cases of cacao and six inarched mangoes were received from the Bureau of Plant Industry of the Department in Washington. A portion of these plants were set out on the station grounds in Honolulu and the remainder placed at Hilo, where previous plantings of cacao had been made.

The distribution of Bluefields bananas begun in May, 1906, was continued during July and August, over 1,000 suckers of this fine type of banana being distributed throughout the Territory.

In a cooperative agreement between the Director of the Office of Experiment Stations and the Chief of the Bureau of Plant Industry Dr. N. A. Cobb, who had been employed as pathologist by the Hawaiian Sugar Planters' Association in the study of the diseases of cane, was given a commission to prepare a report on the fungus diseases of crops other than cane in Hawaii, and this report will be published as a bulletin of this station.

The special agent, assisted by the station horticulturist and entomologist, made representations to the Territorial Board of Commissioners of Agriculture and Forestry in an endeavor to secure their cooperation in a survey to determine the present distribution of the mango weevil. This weevil, which is a very serious enemy of the mango fruit, as has been previously noted, had only recently been introduced into Hawaii, and it was felt that if precautions could be taken in time there was a good opportunity to entirely destroy the pest. The board of agriculture, however, considered that the weevil had already become so widely distributed throughout the group that it would be impossible to do anything, and the matter was therefore dropped. The officers of this station consider it extremely unfortunate that efforts should not have been made at the time of the first discovery of this mango weevil to prevent its further distribution.

The special agent made an extended trip through Maui and Hawaii in an investigation of the rubber industry. He also visited the location on Maui where the variety test of grapes was being conducted. As a result of reports made by him in regard to the suitability of certain lands in Puna, an extensive rubber plantation has been established, which has already (July 1, 1907) over 12,000 trees growing in the fields.

In November, 1906, this station cooperated with the manager of one of the local sisal plantations in an investigation of the sisal industry in Yucatan. Much valuable information was secured, which is available for publication in a second report on the sisal industry in Hawaii.

The special agent has prepared reports in regard to the work of the station for the governor of Hawaii, at his request, and also a report in regard to the cooperative work of the station for publication in the annual report of the Board of Agriculture and Forestry.

During the regular session of the legislature which convened in February, 1907, the director visited the island of Lanai at the request of the house committee, which had been appointed to investigate the Lanai land exchange, and made a report to the legislature on the agricultural possibilities of that island.

Considerable work has been done for other branches of both the Federal and the Territorial government, among these cement analyses for the U. S. Army Engineer Corps, and a number of analyses and examinations of imported goods for the collector of customs. This station has also cooperated with the Navy Department in sending collections of seeds and plants to the naval stations in Guam, Tutuila, and the Philippines.

A number of changes have occurred in the office and staff. The more important of these are the appointment of Mr. F. G. Krauss as agricultural expert in charge of rice investigations, at a salary of $2,000 per annum. Half of this amount during the fiscal year 1907 was contributed by the B. P. Bishop Estate (Limited). The horticulturist, Mr. J. E. Higgins, was promoted from $1,700 to $2,000. Miss A. R. Thompson was appointed assistant chemist, and the former chemist, Mr. E. C. Shorey, was transferred to the Bureau of Soils, U. S. Department of Agriculture.

Besides the $15,000 appropriated by Congress this station has received during the fiscal year 1907 from private and other sources $13,518.63. This includes a balance of $2,267.09 remaining unspent from the Territorial appropriation of 1905. A deficiency appropriation of $2,000 was made by the legislature in May, 1907, to assist the rice, tobacco, and rubber investigations. A Territorial deficiency appropriation of $1,873.86 was received to settle indebtedness which was incurred in the erection of a fireproof library, laboratory, and office building, for the erection of which the legislature made an insufficient appropriation in 1905.

The Bernice Pauahi Bishop Estate (Limited), contributed $1,000 for rice investigations and $200 for rubber experiments. The Ii Estate (Limited), contributed $128, or its equivalent, in the free rental of 3.2 acres of rice land for the benefit of the rice investigations. The Honolulu Merchants' Association contributed $50 toward the cost of the fruit marketing experiments conducted by the horticultural department. Mr. James B. Castle contributed $358.60 toward the expense of establishing a citrus orchard on Tantalus, and $1,000 for tobacco experiments on Hawaii. The Hawaiian Bee Keepers' Association contributed $675 toward the cost of the entomologist's trip to Washington, D. C., in their behalf. Dr. Wm. S. Myers, of New York city, gave $187.50 for the continuation of the rubber experiments. Mr. George N. Wilcox gave $200 for rubber experiments and $500 for tobacco experiments. Hon. A. S. Wilcox contributed $500 for tobacco. Messrs. Geo. P. Thielen and Joseph P. Cooke each contributed $1,000 for tobacco. The American Sugar Company, the Parker Ranch, and the Stock Breeders' Association gave $175 toward the cost of investigations by the entomologist of insects affecting stock. The receipts from the sale of farm products amounted to $400.88. The total amount expended for this station during the fiscal year 1907 was $33,518.63, of which $20,000 was appropriated by Congress.[a]

During the year three press bulletins were issued—No. 17, The Mango Weevil; No. 18, All About the Hawaii Experiment Station; and No. 19, A Preliminary Report on Rice Investigations. Editions of 4,000 copies of each of these bulletins have been distributed.

CHEMICAL INVESTIGATIONS.

The only project completed during the year has been that of honey analysis. This work has been carried on by the station chemist, Miss Alice R. Thompson, in cooperation with the entomologist. Complete analyses were made of 49 samples of honey of known derivation and the results of this work are now available for publication.

Considerable routine work was accomplished, including a number of miscellaneous soil analyses, the analyses of waters to determine the relation of their salt content to the growth of rice and other irrigated crops, analyses of rubber, soils, and of additional samples of Hawaiian feeding stuffs.

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[a] Besides these cash contributions the station is indebted to the Interisland Steam Navigation Company (Limited), of Honolulu; The Oahu Railway and Land Company (Limited), of Honolulu; The Kahului Railroad Company (Limited), of Kahului, Maui; and the Hilo Railway Company (Limited), of Hilo, Hawaii, for gratuitous transportation of the members of the station staff.

Early in the year connections were made with the mains of the newly organized gas company, so that we were able to discontinue the use of the cumbersome and costly gasoline gas machine, upon which the station had previously depended for its laboratory supply.

TOBACCO.

As has been noted above, the station received the benefit of $4,000 in private contributions for continuing the tobacco investigations, concerning which a number of reports have been issued. In January, 1906, the station was given the use of lot 19, Paauilo Homestead, a body of land about 1 mile distant from the plat which had previously been leased from the Louisson Brothers, in Hamakua, Hawaii. At the request of the special agent, the acting governor of Hawaii, Hon. A. L. C. Atkinson, secretary of the Territory, confirmed a reservation made by Hon. James W. Pratt, commissioner of public lands, reserving lot 19 for the use of the station for a period of three years. Field work was not begun until February 15. Three thousand dollars of private funds being at that time available, the work of preparing land for planting was immediately begun. A part of the land was cleared of the abandoned coffee, with which the land was covered, along with weeds and grass. About 2 acres was then plowed and 3 acres intended for immediate planting was partially hoed and then cultivated. As soon as the ground was in shape transplanting was begun. Work was commenced so late in the year that we were able to plant only about 3½ acres, instead of 5 or more, as originally planned. As soon as the field work was under way lumber was purchased for the erection of a curing barn and fermenting shed, seed houses, and labor quarters. A curing barn capable of handling 5 acres of tobacco was rushed to completion, but even then some of the tobacco was overripe before the structure was finished. About $2,500 of the amount privately contributed was expended for buildings and other permanent improvements. The work was begun late in the year, so that everything was hurried during the entire season.

The results were better than in any previous season. The entire crop was cured and fermented in the new tobacco barn, and, although probably 600 pounds of the crop was lost through ripening before we were ready to care for it, a crop of 3,000 pounds of cured tobacco was secured from 3½ acres of land. A quantity equal to 6 or 7 bales has been distributed in small amounts to tobacco dealers in the United States and Europe. Two New York firms received 1 bale each, and the station now has on hand 23 bales of finished tobacco. The best tobacco grown this year was the Sumatra, although the Cuban grades were of very excellent quality. The reports in regard to the quality of our tobacco are uniformly favorable, buyers being very enthusiastic in regard to colors, texture, and burn of leaf. The tobacco is very mild and of excellent flavor.

The legislature at its session early in 1907 having omitted its appropriation for assistance to this station, the demonstration with this crop was discontinued. It is believed that this demonstration, which has been continued over a period of three years, has definitely established the fact that cigar-leaf tobaccos of the very best wrapper and filler types can be produced on a commercial scale in certain favorably located districts in Hawaii.

ENTOMOLOGICAL INVESTIGATIONS.

In July and August, 1906, the entomologist finished his work with the distribution of the top-minnows. He personally distributed a number of these mosquito larva-eating fish on the windward side of Oahu, in the vicinity of Hilo, on the island of Hawaii, and on several points on the island of Kauai. This distribution having been completed, this line of investigation was discontinued.

In September, 1906, a request was made for the services of the entomologist in the control of a serious outbreak of pineapple insects on the island of Kauai. The cause of serious losses among fields of newly set pines was found to be the pineapple scale and the pineapple mealy bug. Experiments were made both in dipping and in fumigating the suckers which were being transplanted. It was found that the hydrocyanic-acid gas method was entirely efficacious, cheap, and easy of application.

The principal entomological work of the year has been an investigation of the problems affecting the honey industry in Hawaii. The entomologist has visited all the principal apiaries and has made a very exhaustive study of the conditions of the industry. Fifty-four samples of honey of known origin were collected; 49 of these were analyzed by the station chemist.

Hawaiian honeys are largely of a type entirely different from those of the mainland. The present annual production amounts to upward of 600 tons. One-fourth of this, or about 150 tons, is honeydew honey, the source of which is not floral nectar, but the secretions of insects affecting the sugar cane and other sugar-producing plants. About 250 tons are a mixture of honeydew honey and floral honey, compounded by the bees during the time when there is a shortage of floral nectar. About two-thirds of a crop is therefore of a type but little known on the mainland. This pure honeydew honey and the mixed honeys are sold to the baking trade, and do not enter into competition with any of the natural product offered for sale in the retail markets.

Through the efforts of the entomologist the prices obtained by producers of this honeydew product have been much increased. Before their baking qualities were ascertained, the Hawaiian honeydew honeys entered into more direct competition with Australian and other cheap grades, which are most largely used in the manufacture of shoeblacking and in other special lines of industry. In former years, when only this market was known to be open, prices ranged from 2 to 3 cents per pound. Now, through the efforts of our entomologist, large consignments have been sold to the wholesale baking trade, prices ranging from 4 to 6 cents per pound being realized.

Bakers and confectioners consider honey of this type, on account of its noncrystallization, as much more valuable in their industry than the grades obtained from purely floral sources.

On April 5, 1907, the entomologist left for Washington for the purpose of taking up with the Chief of the Bureau of Chemistry the question of the conformity of Hawaiian honeys to honey standards. Subsequent to the passage of the Food and Drugs Act, the question had arisen whether or not Hawaiian honeys of the pure honeydew and mixed honeydew types were or were not adulterated. Mainland buyers claimed that these honeys were not pure. The analyses of Hawaiian honeys, made by the chemist of this station, had plainly indicated that while these honeys are pure in the sense that they are not artificially adulterated, there is wide divergence in their analysis from previous honey standards.

While somewhat abnormal in their constituents, these honeys are recognized as natural products, and as such can be marketed if properly labeled. Those polarizing to the left will be recognized as pure honey, while those polarizing to the right should be marked in a distinctive manner, and the name "honeydew honey" has been suggested for them.

In connection with this honey work a beginning has been made in the investigation of the feasibility of feeding back the inferior grades of pure and mixed honeydew types for the production of wax. Wax of good quality sells for from 35 to 40 cents per pound, while honeydew honeys sell from 2½ to 4½ cents per pound. If it proves practicable to feed back this grade of product, or, more properly, if 1 pound of wax can be produced by feeding back from 4 to 8 pounds of honey, there is bound to be a wider margin of profit in the production of wax than through the marketing of this cheap grade of honey.

Studies were also made of the races of bees with a view to improvement of the local breeds.

Another line of investigation which has been begun is a study of the insects affecting live stock, among these being flesh flies, horn flies, mites, ticks, bots, fleas, and other pests. On his return from Washington the entomologist visited some of the ranches in Texas and southern California, making preliminary studies of the conditions affecting pests of stock in these sections of the country.

Investigations were continued on household pests and pests infesting stored products, and a demonstration was made of methods for the control of the cigarette beetle in tobacco and cigars. The cigarette beetle occurred in a new rôle as a household pest, being discovered in enormous numbers in a residence in Manoa Valley infesting the paste underneath the wall paper.

Other outbreaks of minor importance were investigated, such as an epidemic of fleas in several sections of the city. Considerable losses in furniture and basket ware, caused by termites, various wood-boring insects, and the bamboo beetle, were prevented.

As the rubber industry is attaining considerable proportions, studies have been commenced of the injurious insects affecting rubber trees. The entomologist visited the rubber plantations on Maui, and has made studies of the life histories of some of the bark and wood-boring insects with a view to their control.

HORTICULTURAL INVESTIGATIONS.

The principal work of the year was a fruit shipping experiment. The horticulturist left Honolulu August 1, 1906, taking with him about 4 tons of pineapples, avocados, papaias, and bananas. This shipment was landed in San Francisco August 7 and was transshipped at once to Portland, Oreg., where the entire shipment was unpacked and examined. A portion of it was disposed of in Portland and the horticulturist took the remainder to Astoria, Tacoma, Seattle, and Vancouver. Returning to San Francisco he visited Fresno to investigate the sweet-potato industry. He also investigated the general fruit markets in San Jose, Stockton, Sacramento, and Oakland, and, before returning, visited Luther Burbank's gardens in Santa Rosa. The object of this comprehensive experiment was to determine the best methods of packing, handling, and marketing tropical fruits. An investigation was also made of the extent of the market for these fruits on the Pacific coast. Selected packages were shipped to commercial bodies and to the governor of each of the mountain States as far east as Colorado. One package of pineapples was shipped to the special agent in charge of the Alaska Experiment Station at Sitka. This experiment demonstrated the possibility of the shipment of avocados and pineapples in cold storage to any point which can be reached by direct shipment from Honolulu, Hilo, and other island ports. Interesting facts were determined in regard to methods of packing and the use of different styles of crates. The most striking feature of the whole experiment was the demonstration of the value of fumigation with formaldehyde gas to prevent the losses caused by the pineapple rot, *Thielaviopsis ethaceticus.*

This fungus is the cause of the disease of sugar cane known as the pineapple disease; so-called, not because it was originally a disease of pineapple, but on account of the odor which is produced in cane affected by this disease. In cane it is a disease of the ripe stalk, the fungus attacking the plant at the stage when it contains the most sugar. When this fungus attacks the pineapple it is chiefly in evidence during the ripening of the fruit and does not apparently affect any other part of the plant. It has been demonstrated that infection of the pineapple fruit occurs at the base, either through wounds caused by mealy bugs and other sucking insects, or where the fruit has become bruised or injured through the tearing off of the bracts which subtend the fruit. The fungus also gains entrance to the fruit through the fresh surface of the cut stem. Positive results were obtained when these bracts were cut instead of being pulled, and equally positive results were obtained by cutting the stalk 2 or 3 inches below the fruit. Preliminary experiments were made in dipping the fruit in a 4 per cent solution of formalin, but it was found that this method caused changes which would interfere with the attractiveness of the fruit. It was found that fumigation caused none of these changes, but did exercise a definite control to prevent infection. The fumigated fruits which were lost by rotting in transit were those which were apparently seriously infected previous to shipment and previous to fumigation. It was demonstrated that a favorable method of fumigation is that proposed by the Maine State board of health, through the use of permanganate of potash and commercial formalin. A full and detailed account of these experiments was published in a bulletin of this station.[a]

Other points which were determined in regard to pineapples are the value of glazed paper as a wrapping material for the fruit. By the substitution of paper for hay or straw, which substances are commonly used in the packing of Hawaiian fruit intended for shipment, the package can be decreased at least one-third in size and the weight also very considerably diminished. Pineapples that were wrapped in paper reached the market in very much better condition than those packed with hay in crates.

The permanent orchards on the station were largely increased during the year 1907. The avocado and mango orchard was extended so that about 1½ acres are now planted with budded, grafted, and inarched stock of many of the best varieties.

Through the cooperation of Mr. James B. Castle, about 2 acres of land were cleared on the upper portion of the place at an elevation of about 1,000 feet. This has been planted with a collection of some of the best Californian varieties of citrus fruits, figs, loquats, and grapes. About one-third of an acre has been planted with papaias for breeding and crossing work. A large number of seedling citrus trees have been set out with a view to making in this location a bud collection of the best island types. Besides contributing funds for clearing the land and planting it, Mr. Castle has volunteered to care for the orchard during the coming year.

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[a] Hawaii Sta. Bul. 14.

A large collection of rubber plants and miscellaneous economic plants has been set out on the clearings above the 1,000-foot level. These were all grown by us in our greenhouses from seeds purchased from dealers in tropical seeds and plants.

On the lower part of the place about 4 acres of new land has been planted, as follows: One acre of mulberries, obtained through the Bureau of Entomology, U. S. Department of Agriculture. This planting represents the best varieties for the production of silk, so that the station will have its own supply for further investigations in this line of work. One acre has been planted with citrus trees including grapefruits, oranges, lemons, and limes. One acre has been set with 5 species of rubber—*Castilla elastica*, *C. lactiflua*, *Manihot glaziovii*, *Cryptostegia madagascarensis*, *and C. grandiflora.* The remaining acre has been planted with a miscellaneous collection of tropical fruits and economic plants, including stock grown in our own greenhouses and plants supplied by the Seed and Plant Introduction of the U. S. Department of Agriculture.

About 1½ acres of roselle was cultivated on the lower part of the station as a demonstration of the practicability of growing this fine fruit. A quantity of the fruit was sold, and a good many lots were distributed for the purpose of demonstrating its value in the making of jams and jellies. Seed was saved from selected plants and has been widely distributed throughout the Territory.

The horticulturist visited the Parker ranch, on the island of Hawaii, supervised the setting out of a large deciduous orchard, consisting of apples, pears, plums, peaches, apricots, cherries, walnuts, almonds, and figs. Two orchards of deciduous fruits have been established on the Parker Ranch, one at an elevation of about 3,000 feet, on the northeastern end of the ranch, and one at 5,000 feet in the Waiki district. This cooperative experiment will undoubtedly prove of great value in subsequent years.

The horticulturist had the general supervision of a fruit exhibit in connection with the agricultural show held in Honolulu, December, 1906. In cooperation with the Hawaiian Poultry Association the horticulturist prepared an exhibit under the joint auspices of the Farmers' Institute of Hawaii and the Hawaii Agricultural Experiment Station.

RUBBER.

In the summer of 1906 attention was called to the existence of two groves of rubber trees on the island of Kauai, each containing about 100 individual trees. One of these groves, at Koloa, was planted in 1893, and seed from these trees was planted at Lihue in 1899, so that the two groves are, respectively, 13 and 7 years old. These trees are of the Ceara variety, which is being extensively planted in these islands.

It was at once suggested by some of the planters interested in rubber cultivation that this station make a tapping experiment to determine the amount and quality of rubber obtainable. As this station had no funds, work was not begun until January 1, 1907, when the B. P. Bishop Estate (Limited), and Mr. George N. Wilcox each contributed $200 to assist the work.

The first work done was on a few isolated trees from 4 to 10 years old on the experiment station grounds in Honolulu. Three months were devoted to laboratory investigations in regard to the behavior of the latex under different coagulents. Some preliminary work was done to determine the form of tapping tools and method of tapping.

In April, a satisfactory method having been worked out, the special agent, accompanied by Mr. Q. Q. Bradford, farm foreman, went to Lihue. The management of the Lihue plantation lent the station hearty cooperation, erecting a small shed in the rubber grove and providing entertainment and horses for the use of our foreman. The Lihue grove of 7-year-old trees occupies an old taro patch in the bottom of a gulch. Surrounding it is a planted forest several hundred acres in extent. A living stream of water runs through the middle of the grove and the land is quite swampy. The trees vary greatly in size, from 6 inches to 30 inches in circumference of trunk, at 3 feet from the ground. No care appears to have been given the trees during the entire period of their growth. Some of the trees show a clear, straight trunk, 30 feet in height; others fork near the base. It was found that only about 70 trees out of the full number, 110, were suitable for tapping, owing to their size or shape.

A set of rubber tapping knives such as are used in Ceylon for work on Hevea had been purchased, but it was soon found that these were entirely unsuited for thin-barked trees like the Ceara, and considerable work was devoted to making a form of knife which would be satisfactory. After many experiments the system of tapping decided upon was the half herringbone, with one vertical cut and laterals a foot apart extending half around the tree. Where the full herringbone system was employed it was found that only the uppermost and lowest laterals yielded a full flow of latex. Two experiments were outlined, one to tap every day, the other alternate days.

The Ceara latex coagulates almost at once when the channels are made. We therefore adopted a method of trickling water over the cut surfaces, and soon found an addition of ammonia retarded coagulation and continued the flow until the feeding area was practically exhausted. The mixed water and latex is collected at the foot of the tree. The tapping was begun at 5 o'clock a. m. Two trees averaging 28 inches in circumference were tapped for nine consecutive days, with the full herringbone system from the ground to 5 feet, there being five laterals 1 foot apart. These two trees yielded 8 ounces of dry rubber in nine days. Two other trees were tapped on alternate days for a period of two weeks and yielded 4 ounces of dry rubber in that time.

Work was begun at Koloa in May. The trees, 44 inches in circumference and 13 years old at the time tapping was begun, were almost bare of leaves, the resting period being about ended. Two of these 13-year-old trees were tapped every day for nine days and yielded 12¼ ounces of dry rubber. It was not considered advisable to tap alternate days on account of the leafless condition of the grove.

In June a number of 4-year-old trees at Koloa, averaging 19 inches in circumference, were tapped every day for 9 days, yielding only ½ ounce of dry rubber. These trees were entirely bare.

This tapping work has been very suggestive, and there are many points that have arisen which we shall endeavor to work out during the coming year. The Ceara trees seem to be very susceptible to the atmospheric and other conditions, at least as far as the flow of latex is concerned. The flow is apparently greatest in the early morning at about sunrise. The amount of sunshine received by the tree apparently has some influence on the amount and flow of latex. These experiments are only in the preliminary stage, and it is too soon to draw conclusions, but if any results can be predicated the indication very strongly suggests the value of daily tappings rather than tapping the tree at longer intervals. Trees tapped late in the forenoon, at midday, or in the afternoon, yield almost no latex. At about sundown there is apparently an increase of tension and the latex flows more freely.

Four-year-old trees at Koloa yielded at the rate of 10 ounces of dry rubber per tree per annum, supposing it possible to tap every day. Seven-year-old trees at Lihue yielded at the rate of 10 pounds per tree, while 13-year-old trees at Koloa yielded at the rate of 15 pounds of dry rubber per tree. Neither the Koloa nor Lihue trees were in good condition at the time of tapping. Those at Lihue are in a swampy location, where the ground is always saturated with water. Those at Koloa are in a much drier location, but have been choked with guava and lantana and overrun with vines. All the tappings were made while the trees were just entering their period of rest or during the time when bare of leaves. Nevertheless, the results are encouraging. The indications are that the Ceara rubber tree will grow in almost any location in these islands, from sea level to 2,000 feet, and wherever the conditions are sufficiently favorable to permit the attainment of a trunk diameter of 7 or 8 inches these trees will yield an enormous quantity of rubber of most excellent quality.

The quality of the rubber has been good. The variations in quality apparently depend more upon the coagulating medium than upon the character of the latex itself, although in this respect there is wide variation. A great many experiments have been made with various methods of coagulating the latex, but it is too soon to announce results. The best qualities thus far produced have been made by neutralizing the ammonia in the latex and coagulating by adding a hot concentrated solution of ammonium sulphate to which a small amount of formalin has been added. Other coagulents that have been experimented with are acetic acid, sulphuric acid, tri-chloric acid, formic acid, sea water, ammonium sulphate, various copper and other mineral salts, sodium sulphate, etc. A very excellent quality of rubber may be separated out by simply churning the mixture of water and latex. Sulphuric acid gives goods results, provided but little more than enough to neutralize the ammonia in the mixture is used. An excess of sulphuric acid apparently causes deterioration in the quality of the rubber.

RICE.

An investigation of the problems of the rice industry was begun July 1, 1906, funds for the purpose of a cooperative experiment having been provided by the Bernice Pauahi Bishop Estate (Limited), and the Ii Estate (Limited). The trustees of the Bishop estate gave $1,000 for this work, and the Ii estate contributed the lease of 3.2 acres of rice land, located at the junction of King street and Kalakaua avenue, in the city of Honolulu. Mr. F. G. Krauss, who had been agricultural instructor at the Kamehameha Boys' School for the preceding five years, was appointed an agricultural expert in this office to have charge of the work. Operations were commenced about August 1, 1906, and consisted of variety tests of 130 different rices obtained in the islands through the Bureau of Plant Industry, U. S. Department of Agriculture, and through the bureau of agriculture, Manila, P. I. In addition careful selections had previously been made from individual plants, representing some of the best strains of rices now being grown in Hawaii. Two crops of rice have been grown during the period from August 1, 1906, to August 31, 1907.

The results of the variety test have been that one variety, seed of which was originally obtained by Dr. S. A. Knapp in Egypt, has proved to be better than any rice ever grown in these islands. This

Egyptian strain has a very large, flinty grain, heavy panicle, heavy straw, good leafage, and is of the type demanded by the largest consuming trade in these islands. Its milling qualities are very much superior to those of any other variety which has been produced in the islands, the hulls approximating only 20 per cent of the total weight of paddy, as compared with from 26 to 30 per cent for the best Japanese types, and 28 to 36 per cent for the ordinary Hawaiian variety. In addition to this Egyptian type three other strains have shown marked superiority to the ordinary Hawaiian-grown rices. These are, in order of merit, a Philippine variety, a strain of the Gold Seed from Georgia, and a Japanese type, seed of which was secured direct from Japan.

This Japanese variety produces a crop in three-fourths the time required for the maturity of the Hawaiian variety, provided it is transplanted from the seed bed at the proper time. It is of the Kiushu type, yields as heavily as the Hawaiian variety, mills from 10 to 12 per cent better, produces only about two-thirds the amount of straw, and is therefore less exhaustive on the rice lands. It is the type of rice now most largely consumed in Hawaii by the Japanese laborers on the plantations. A further advantage of the adoption of this variety will be that two crops can be grown each year, with a long rest between crops to permit the drainage of the fields and their better tillage and preparation. The station now has 50 pounds of this seed on hand, and will probably have 1,000 pounds at the end of the next crop. The field was thoroughly rogued and the strain is being propagated from the best individual plants of the whole field, thus laying the foundation for the production of pedigree rice.

The so-called Hawaiian rice is derived from original Gold Seed, South Carolina stock, the first rice cultivated in Hawaii having been thus obtained. The Georgia variety, mentioned above, is hardly to be distinguished from Hawaiian rice. A number of selections have been made of individual plants showing the best individual characteristics in yield of grain, form of panicle, stalk, and leafage, and vigor of growth. An increase of 25 per cent of yield of paddy has already been produced from only the second selections from individual plants. The advantage of this use of pedigree stock of seed derived from a single parent is greater uniformity in the size of grain, the yield, and the time of ripening. The substitution of such pedigree stock will tend to decrease the very large milling losses which have been characteristic of the Hawaiian rice industry. The ordinary Hawaiian rice, while largely of the Gold Seed type, is really a mixture of a great many different types, so that to get the best results in harvesting some of the rice will be so ripe that the grain shatters, while a portion of the plants in the field have perhaps barely attained a sufficient degree of ripeness to warrant their being cut. The losses in milling are due to the varying sizes and types of grain and their varying stages of maturity. The miller sets his burrs to accommodate the average size of grain in the run, so that grains which are too large are broken and those which are smaller than the average are insufficiently milled, causing bad color in the product.

The uniformity of grain will undoubtedly prove of greater importance than any other single factor in the production of this crop. This uniformity can be produced only by the production of pedigree stock; that is, stock derived originally from a single parent plant.

Three varieties of dry-land rice have been selected from the original variety collection. An interesting point about these dry-land rices is that they produce a better crop without irrigation than with it. The value of dry-land rice is going to be not so much the production of grain, because dry-land rices tend toward the starchy type of grain rather than the flinty, but the production of forage. The culm and leafage of the dry-land types of rices are soft and pliable, lacking the silica that causes the harshness of irrigated sorts. These strains produce a quality of hay which is greedily eaten by horses and cattle. The present outlook is that dry-land rices will fill a very important need in Hawaii in the production of hay and forage.

Fertilizer experiments have been conducted for two crops in pot, plat, and field experiments. While it is perhaps too early to draw conclusions, the indications are that an increase of from 15 to 20 per cent of grain per acre can be induced by use of commercial fertilizers of suitable composition.

Early in the year orders were placed for a number of types of agricultural machinery not hitherto used in the rice industry in Hawaii. These included disk tillage implements and the twine binder. Disk tillage is promising, provided machinery can be secured which will give a penetration of from 6 to 8 inches. The type of cut-away, or disk plows and disk harrows, which the station has secured, would only penetrate about 4 inches, although the manufacturers claimed a much greater penetration. It was found that 4.5 acres of rice land could be plowed per day with a 5-foot cut-away bog plow and four horses, as against from 1 to 1½ acres with two water buffalo, or from three to four horses on a 10-inch mold-board plow turning the soil to a depth of about 6 inches. This is the only advantage which this form of implement has over the improved types. If manufacturers of disk implements will evolve a type of bog plow that will turn the ground from 6 to 8 inches in depth, there is no doubt that they would be immediately adopted by the Chinese rice growers.

A number of trials were made in the harvesting of rice with a 5-foot twine binder harvester, and it is believed that the Chinese rice growers would adopt this type of machinery if they could secure a lighter machine.

With an extra week's drainage previous to harvesting, fully one-half of the total area of rice lands in Hawaii can be harvested by means of machinery. The results of the preliminary harvesting tests indicated that even with our comparatively heavy machine one good team of two heavy draft horses, or from three to four medium horses and three men—that is, a driver and two men to follow the machine and shock the grain—will do the work of from 25 to 40 men cutting with a sickle. The increasing shortage of labor in the rice fields and the corresponding increase in prices of day labor will make the substitution of machinery for hand methods imperative. The expert in charge of rice investigations is in correspondence with a number of manufacturers in the United States to see whether a light machine can not be produced which will do the work required of it.

REPORT OF THE ENTOMOLOGIST.

By D. L. Van Dine.

INTRODUCTION.

Correspondence, the collection of economic insects, the entomological library and records demand a great part of the time of the entomologist. The collection contains only the principal injurious insects of the islands, together with allied species and some of their parasitic and predaceous enemies. The specimens are arranged in exhibition cases, are authoritatively determined, and form no small aid in acquainting those interested with any particular species under consideration. To combat intelligently an insect pest the individual must know the appearance, form, life history, and habits of the species and the nature of the injury. To this end the collection is principally devoted.

As to the records, their units seem insignificant alone, but together they form a detail of information that can be brought together with effect in dealing with an insect of economic importance. The value of these records will increase as accessions are made from year to year.

Important additions have been added to the library during the year. Those relating to Hawaiian entomology are included in this report.

The writer visited Wahiawa, Oahu, and Koloa and Lihue, Kauai, to study further the insects affecting the pineapple. Trips were made to Pearl City and Waianae, Oahu, in the interests of bee keeping. Personal investigations relating to the scale insects attacking the mango and fig and spraying experiments to control the same were made at Moanalua, Oahu. Detailed studies of the insects affecting live stock in Hawaii were begun on Molokai. A trip involving three months' time was made to Washington, D. C., southern Texas, and southern California, in the interests of Hawaiian honey, plants suitable for introduction into Hawaii for bee pasturage, and insects affecting live stock.

The writer takes advantage of this opportunity to express his gratitude for continued courtesies extended during the year by mainland and foreign workers. Particular mention should be made of the helpful aid in information, suggestions, and determination of material received from Dr. L. O. Howard and his associates of the Bureau of Entomology of the United States Department of Agriculture.

INSECT INJURY IN HAWAII.

In Hawaii the relative loss from insect injury is considerably higher than on the mainland of the United States. In the latter it is estimated to be not less than one-tenth of all farm crops. Local opinion has been molded to attribute the unusual injury from insect pests in Hawaii to the fact that Hawaiian conditions are radically different from those of other countries, and especially those in other portions of the United States. This explanation is a very plausible one when supported by the further facts that the country is insular, one of the most isolated portions of the earth's surface, semitropical in climate, and the injurious species of insects are introduced from abroad, and in the majority of instances are unaccompanied by their special parasitic or predaceous enemies. The conclusion is that remedies applicable elsewhere are not practical here. However, the " peculiar nature " of Hawaiian insular conditions and climate comes far from explaining the reason for the greater ravages of Hawaii's insect pests. The term " peculiar " has come to possess an importance it does not deserve.

Hawaii has conditions peculiar to no other country, but in that respect is similar to every other country—each differing according to its own altitude, latitude, and climate. Details of the differences in pests, crops, methods of agriculture, climate, and differing habits of the host or pest under the varying conditions of location will indicate modifications in the methods of insect warfare to be employed. It is to be admitted that conditions peculiar to any country or locality necessitate a variation in the methods of insect control, but this variation is only in the methods and not in the fundamental principles underlying the science.

The following conditions contribute to the relatively high ratio of insect injury in Hawaii as compared with the percentage of loss on the mainland:

(1) Cultural methods in relation to insect injury and the use of insecticides have been little understood on the plantation and on the farm. Until there is a more general effort to control the insect pests of Hawaii by cultural and direct measures, it will be unfair to compare conditions in Hawaii as regards insect injury with those of another country where such measures are universally employed.

(2) Sugar-cane is the principal agricultural crop of Hawaii. An enemy of this plant has necessarily a great advantage because of the immense area devoted to its cultivation. Aside from the advantage of abundance of food, the growth of cane, unlike wheat or corn in a

temperate climate, is continuous. In any locality it is possible to find sugar-cane in various stages of development at all seasons of the year. Not only an abundance of food, but a continuous supply is assured. Further, until recent years varieties of cane and its culture were not considered in their relation to insect injury. Thus when an introduced pest, the sugar-cane leaf-hopper (*Perkinsiella saccharicida*), made its advent into the cane fields several years ago, its injury amounted to millions of dollars.

(3) There is no check to insect development in Hawaii by radical changes of temperature, the equable climate favoring the development of brood after brood throughout the year.

(4) The efforts of diversified farming have been undertaken, in the majority of instances, on land recently cleared and in the midst of areas not under domestication. These smaller areas under cultivation have naturally attracted a horde of injurious insects, present in the locality but inconspicuous because of the check that natural conditions enforce. Further, the individuals undertaking the efforts of farming have in many instances not been farmers and have been unprepared for insect injury and helpless when the destruction of the crop has been threatened.

(5) Horticulture is an undeveloped industry. The effort to produce fruit is confined mainly to trees and vines growing under most adverse conditions in crowded dooryards, uncultivated and uncared for. The percentage of insect injury is abnormally high under these conditions.

(6) Crop rotation, a powerful factor in the control of injurious insects in many countries, is not practiced in Hawaii. Agriculture in Hawaii is not a combination of general farming industries, but is necessarily devoted to crops that must seek the world's market and are thus highly specialized.

(7) Injurious species of insects have been introduced without their special parasitic and predaceous enemies. This has given a great impetus to the development of some species because of the absence of one of nature's important checks. A great deal has been done on the part of the local government to remedy this condition by the introduction from abroad of many important special enemies of some of the more prominent insect pests.

(8) While legislative action is rigidly enforced to prevent the further introduction of injurious insects, no regulations have been outlined or enforced for the destruction of injurious species already established. There is little incentive for an individual to destroy the pests of his own trees and plants when indifferent owners all about him are allowed to breed unlimited numbers of the same species.

THE SWEET-POTATO WEEVIL.

(*Cylas formicarius.*)

The sweet-potato weevil (see fig. 1) appeared in injurious numbers in sweet potatoes at the Lahainaluna School on the island of Maui in January, 1907. Specimens of infested potatoes (see fig. 2) were received from Mr. Charles Flack, at that time agriculturist of the school. The crop was nearing maturity and was practically destroyed. The insect is of long standing in Hawaii, being recorded by Blackman and Sharp from the islands of Maui and Oahu in 1885 under the name of *Cylas turcipennis.*[a]

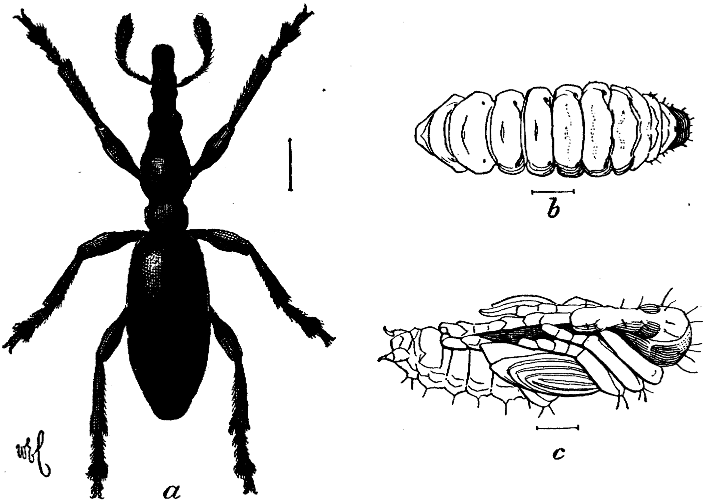

FIG. 1.—The sweet-potato weevil (*Cylas formicarius*): *a*, adult; *b*, larva; *c*, pupa. All greatly enlarged. Natural size shown by lines. (Drawn for the author by Mr. W. E. Chambers.)

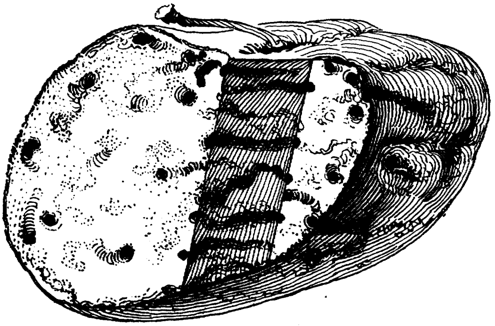

FIG. 2.—Injury to sweet potato by larvæ of the weevil (*Cylas formicarius*). (Drawn for the author by Mr. W. E. Chambers.)

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[a] Memoirs on the Coleoptera of the Hawaiian Islands. Sci. Trans. Roy. Dublin Soc., 2. ser., 3 (1885), p. 253.

This is the first local injury that has come to the attention of the writer. Should the attack of this weevil on sweet potatoes become general it would mean a great hardship to the Hawaiian people in some of the outlying districts, since this crop supplies the staple article of food in many localities.

A common plant in all sandy soil along the seacoast of the islands is a vine the name of which is Pohuehue (*Ipomœa pes-capræ*). This vine is likewise a food plant of the sweet-potato weevil and the destruction of this plant in the neighborhood of sweet-potato fields would be a good precautionary measure. The writer advised Mr. Flack to dig the potatoes and destroy those unfit for use, and cease to plant that crop for one or two seasons, substituting some other crop to replace the sweet potato on the school table. On the advice of Mr. J. E. Higgins, horticulturist of the station, the Polapola banana (*Musa fehi*), a cooking banana of good quality, was recommended to replace the affected crop.

Le Conte and Horn record the sweet-potato weevil in 1876 from Cochin China, India, Madagascar, Cuba, and Louisiana.[a]

Comstock in 1880 reports the destruction of sweet potatoes by this insect in Florida and gives the following description of the weevil and its life cycle:

> The beetle is somewhat ant-like in form. The color of the elytra [wing covers] and of the head and beak is bluish black; that of the prothorax is reddish brown. The yellowish-white oval eggs are laid in small cavities eaten by the parent beetles near the stem end of the tuberous roots. The milk-white larvæ bore little tunnels through the root in all directions, so that the vine dies; and frequently the entire potato is tunneled; these burrows become filled behind the larvæ with excrement. When about to assume the pupa state, the insect forms an oval cavity at the end of its burrow, where it undergoes its transformation.
>
> At the time of my visit to Manatee County, in February, only the perfect insects could be found. On the 17th of May potatoes containing eggs and beetles with a few pupæ were received from Mr. Curry. In our breeding jars these underwent their entire transformation from egg to imago in about thirty-one days, of which eight days were passed in the pupa state. From this it appears that during the present season there have already been at least three generations, and it is impossible to say how many more may appear.[b]

In regard to remedies for the sweet-potato weevil, Riley and Howard say:

> Up to the present time no remedy has been found except to burn all potatoes which are found to be infested. If this should be carefully and thoroughly done throughout a neighborhood, the pest could be greatly reduced. * * * Where it has been abundant in Florida it has been practically stamped out by following the measures just recommended.[c]

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[a] Rhynchophora of America, North of Mexico. Proc. Amer. Phil. Soc., 15 (1876), p. 327.

[b] Report of the Entomologist, Rpt. Comr. Agr. 1879, Washington, 1880, p. 249.

[c] U. S. Dept. Agr., Div. Ent., Insect Life, vol. 5, 1893, p. 261.

In referring to the sweet-potato weevil in Jamaica, the same writers say:

> It seems that only tubers of a certain size are attacked, and early digging sometimes avoids the attack. Sandy soil and deep planting are said to be preventives to some extent.[a]

Undoubtedly the destruction of an infested crop will better insure freedom from attack in the succeeding crop. Deep planting, however, can not be practiced in Hawaii, since cuttings and not tubers are used for seed. After the cuttings have rooted, deep hilling could be employed and the same point gained. If the sweet-potato weevil does become abundant in any locality, probably the best solution of the difficulty for the Hawaiians will be the substitution of some other crop, as the banana, dry-land taro, or upland rice.

THE MELON FLY.

(*Dacus cucurbitæ.*)

Until the winter months of 1898 all cucurbits (watermelons, muskmelons, squashes, pumpkins, cucumbers, etc.) could be grown in Hawaii in abundance and with comparative ease. From that time the increase of an introduced enemy, an insect pest that has come to be known locally as the melon fly, has all but stopped the growing of these products. Mr. B. O. Clark states that he was growing melons at Pearl City, Oahu, at that time and first noticed the fly in the summer of 1897, and that the pest increased to such an extent by the winter months of 1898 and 1899 that attempts to grow melons were given up after those years.

From 1899 to 1903 watermelons and muskmelons, previously very profitable crops, were not grown to any extent. For several seasons past, however, the production of these crops has been on the increase. The reason for this is undoubtedly the persistence of the Japanese growers in protecting their melons from the flies at or immediately after the setting of the fruit. From observations made during the year the writer is of the opinion that watermelons at least can be grown at a good profit.

The first record of the food plants and injury of the melon fly were made in 1898 by Mr. B. O. Clark, then commissioner of agriculture of the local government. The remedies that Mr. Clark suggested at that time, namely, the covering of the infested fruit and vines and the destruction of the infested melons, are today the most effective measures employed against the pest. The reference is as follows:[b]

> The following letter from Mr. Swain makes inquiry about one of the most serious pests on these islands. The reply may interest others:

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[a] U. S. Dept. Agr., Div. Ent., Insect Life, vol. 6, 1893, p. 44.

[b] Official Bulletin of the Bureau of Agriculture. The Hawaiian, Vol. I, No. 27, p. 6. Honolulu, 1898.

"LAUPAHOEHOE, *August 8, 1898.*

"Professor KOEBELE, *Honolulu.*

"DEAR SIR: We have a new pest that has lately come here in the shape of a fly like a yellowjacket, only not so large. It punctures pumpkins, squashes, beans, tomatoes, watermelons, and all other plants of this nature. It lays eggs inside, which form maggots like the samples I send you. You can judge of their work where the things are growing. Can you suggest any remedy? I send you some samples of their work by the S. S. *Kinau.*

"Yours, truly,

"L. C. SWAIN."

"HONOLULU, *August 11, 1898.*

"L. C. SWAIN, Esq., *Laupahoehoe, Hawaii.*

"DEAR SIR: Yours of the 8th instant at hand and contents noted. Professor Koebele is now in the States, but as I have personal experience with the fly you mention and consulted with Professor Koebele in regard to it, I can state he told me of no remedy except covering the vines, and of course this is not at all practicable except for a few vines in a garden. I tried a spray of whale-oil soap, thinking the odor might keep the fly away, but it did not. I shall try a Paris green solution, 1 pound to 200 gallons of water, keeping it stirred frequently, and apply with a spray pump. This will kill the eggs and young larvæ of the codling moth on apple and other fruits, and possibly may do so in this case. The great difficulty in this climate is that frequent showers wash off the poison, and it has to be repeated frequently. The Paris green can also be applied as a powder, mixed with flour or air-slaked lime, in the proportion of 1 part of Paris green to 100 of flour or lime. I would advise collecting all infected squashes and feeding to pigs or other animals or bury them so deep the fly can not get out when it hatches. If all who grow the crops which it breeds in would do so, I think it could be at least checked; the great difficulty would be to know if there is any wild fruit, etc., upon which it deposits its eggs for development. I have not observed it attacking anything but the cucumber, melon, and squash family.

"The following life history, which I have learned by experimenting in a 'hatchery,' may interest you, if you have not already determined the same for yourself. The fly which you describe is more like a small-sized botfly than a wasp, and will be seen hovering about the vines of muskmelons, squashes, etc., and when disturbed darts away very quickly, so rapid, in fact, one can scarcely follow it with the eye. It stings not only the fruit with its ovipositor, but also the young and tender growth of the vines, depositing a number of eggs, which soon hatch into small white maggots that feed on the tissues of the plant or fruit, causing it to decay. After the maggot has attained its growth, it descends into the soil, where it develops into a small chrysalis of a light yellowish-brown color, and in about ten or twelve days comes out a perfect insect, ready to repeat its mission of destruction. I do not know how many generations it will produce in a year, but in the warmer and drier districts I believe it will breed the year through, except possibly a while during the winter months, and then its development is only retarded by the cooler weather, which prevents the chrysalis maturing so rapidly.

"If you will take a squash or other specimen with the eggs or young maggots in the same, placing it in a box containing two or three inches of loose, dry soil, keeping it covered with a piece of glass, you can soon learn for yourself its life history, and perhaps make observations that may lead to means of successfully combating the pest.

"Yours, respectfully,

"BYRON O. CLARK,
"*Secretary and Commissioner of Agriculture.*"

The melon fly belongs to the family Trypetidæ and was described as new to science in 1899 by Mr. D. W. Coquillett, of the Bureau of Entomology, U. S. Department of Agriculture. Mr. Coquillett's description is as follows:[a]

A NEW TRYPETID FROM HAWAII.

Dacus curcurbitæ n. sp. Head light yellow, the occiput, except the sides and upper margin, reddish yellow, an ocellar black dot, front marked with a brown spot in front of its center and with three pairs of orbital brown dots, a black spot on each side of the face near the middle and a brown spot on the middle of each cheek; antennæ, palpi, and proboscis yellow, the latter mottled with brown. Thorax reddish yellow, the humeri, a median vitta on the posterior half of the mesonotum, another on each side above the insertion of the wings, uniting with an irregular band which extends upon the pleura to the upper part of the sternopleura, also a large spot on each side of the metanotum, encroaching upon the hypopleura, light yellow; scutellum, except its extreme base, light yellow, bearing two bristles. Abdomen light yellow on first two segments, reddish yellow on the others, the extreme base, a fascia at the bases of the second and third segments, usually a lateral spot on the fourth and fifth, also a dorsal vitta on the last three segments, blackish or brownish; first segment of the ovipositor of the female slightly longer than the fifth segment of the abdomen. Wings hyaline, the apex of the subcostal cell from a short distance in front of the apex of the auxiliary vein, the marginal and submarginal cells, the median third of the first basal cell and a large spot in upper outer corner of the first posterior cell, brown; anal cell brown, this color encroaching on the third posterior cell and bordering the sixth vein almost to its apex; posterior crossvein bordered with brown, this color extending to the hind margin of the wing; upper end of the small crossvein also bordered with brown. Halteres light yellow. Legs light yellow, the broad apices of the femora and the last four joints of the tarsi reddish yellow, hind tibiæ reddish yellow or dark brown. Length 6 to 8 mm.

Honolulu, Hawaii. Two males and two females bred by Mr. George Compere from the larvæ living in green cucumbers. Type No. 4207, U. S. Nat. Museum.

The food plants are, locally, all the members of the plant family Cucurbitaceæ (watermelons, muskmelons, cucumbers, squashes, pumpkins, etc., including a wild cucurbit, *Sycos* sp.); pods of beans; tomatoes; and the fly has been reported as infesting ripe fallen mangoes and the fruit of the papaya. Mr. F. W. Terry informs the writer that he bred *Dacus cucurbitæ* from larvæ infesting ripe mangoes during August, 1907.

The life history (see figure 3), covering a period of about three weeks, is as follows: The female by means of her strong ovipositor pierces the epidermis of the melon, or other host plant or fruit, and prepares just beneath the surface, in the tissue, an egg-chamber into which through the one incision or opening are deposited several eggs, the number varying from only 5 or 6 to as many as 15. A single fly may be responsible for many such incisions and usually "stings" the fruit several times. The flies are more active in oviposition in the early morning, remaining quiet during the middle of the day and especially on bright, sunny days hidden in the shelter of the vines or foliage about the field during the heat of the day. Observations on the attack of this pest on watermelons indicate that the very young melons are usually chosen for oviposition, presumably because the rind is more tender and capable of penetration. The larger proportion of the melons are infested from time of setting of the fruit until a size of about 3 inches in length is attained. The writer has visited fields where it has been practically impossible to find a melon of that size that was not egg-infested or contained developing larvæ. Larger melons have been found newly infested, but the incision in the varieties observed was near the more tender stem end. This is speaking only of watermelons. Undoubtedly muskmelons and cucumbers are capable of becoming infested much later in their development. In a field where the fly is epidemic, however, the larger melons as well contain the larvæ in all stages of development, the melons showing likewise all stages of decay. Since the enemy is an internal feeder, a correct estimate of the damage can not be obtained by a passing observation. Many melons perfect in shape upon being opened are found to be infested and sometimes completely rotted with the exception of the rind. In some instances the attack is resisted and the wound heals over, but the result is a deformed product, unfit for the market.

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[a] Ent. News, 10 (1899), No. 5, pp. 129, 130.

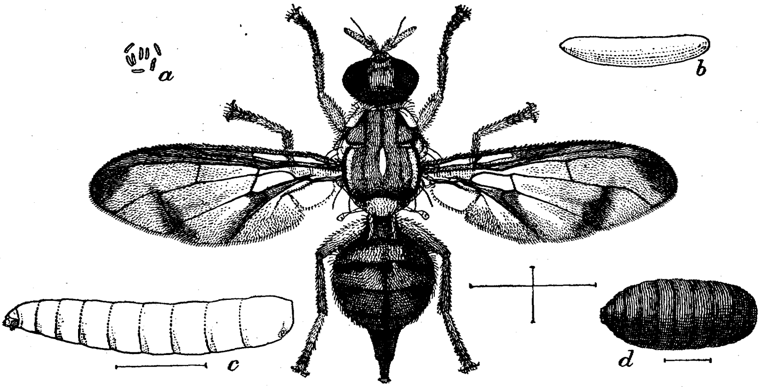

FIG. 3.—Life cycle of the melon fly (*Dacus cucurbitæ*) : *a*, cluster of eggs, natural size; *b*, egg, enlarged; *c*, larva; *d*, puparium. Natural size of adult, larva, and pupa shown by lines. (Drawn for the author by Mr. W. E. Chambers.)

The vines as well as the fruit are infested. This is especially true if the growth is succulent. The vines are usually infested in the larger portions near the crown. During wet weather the decay of the fruit and vines progresses more rapidly than during dry weather. In dry seasons the vines as a rule survive the attack and the wounded portions heal over.

After hatching from the egg the larvæ burrow on into the tissue of the melon, feeding entirely on the interior. When removed from the melon the larvæ have a peculiar mode of locomotion or possibly of protection. They double themselves together and then, suddenly straightening out, throw themselves into the air and quite a distance from the place they occupied. When fully developed the larvæ leave the infested melon or vine and enter the soil directly beneath, where at a distance of an inch or so from the surface they pupate.

No special natural enemies or checks to the melon fly have been observed in Hawaii. Regarding natural enemies Mr. Alexander Craw, superintendent of the division of entomology, board of agriculture and forestry, Hawaii, says:

> From dead specimens of the "melon fly" (*Dacus cucurbitæ*) received by this division from the government entomologists of India, we learn of the existence of several parasites that prevent its seldom or ever becoming a pest there. An effort should be made to introduce these parasites here by way of Hongkong. This would be a difficult experiment, owing to the great distance, but the undoubted benefit to the melon industry of this Territory, in case these parasites were successfully introduced and established, would justify the expenditure of considerable money in the attempt to control this pest.[a]

Prof. W. W. Froggatt, government entomologist of New South Wales, who is making an official trip around the world, recently visited Hawaii. One of the principal objects of his mission was in the interests of controlling the Queensland fruit fly (*Dacus tryoni*), a fly belonging to the same genus as our melon fly. Mr. Froggatt, in company with the writer, visited several districts in these islands where melons were growing, and detailed information on the fly and its occurrence in Hawaii were obtained by him. The writer is pleased to say that Mr. Froggatt will visit the countries of the Mediterranean and India before his return to Australia, and will carefully investigate any enemies of fruit flies in general that occur in those countries. If any special enemies of the group of flies to which our melon fly and the Queensland fruit fly belong are found they will be introduced and established in Australia and it will then be a comparatively easy matter to introduce them from that country into Hawaii. Mr. Froggatt is kindly keeping the writer informed of the progress of his trip, and much of interest to Hawaii will undoubtedly result.

The common preventive measure among the Japanese growers is to cover the young melons with a piece of gunny sack, paper, or some straw as soon as they set. When the melons have outgrown the protection of this covering, they are usually beyond the danger of an attack by the fly. It requires constant attention to cover the newly set melons before they are visited by the overindustrious fly. Protection could be secured by hand pollinating the flowers and covering them before the fruit is formed. There is a difference in the resistance of the different varieties of melons. The harder skinned varieties are less subject to injury, and it is well to select a hard-skinned melon for planting, even at a sacrifice of quality.

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[a] Hawaiian Forester and Agr., 4 (1907), No. 5, p. 113.

All infested melons and vines should be collected at regular intervals throughout the growth of the crop and either burned or buried. Burning is the most effective, but if the acreage is large, holes or pits can be dug at convenient distances through the field and all infested melons and vines collected at intervals of five or six days and deposited in the nearest pit. They should then be covered with earth to a depth of several inches. Overirrigation, producing succulent growth, favors infection of the vines.

After harvesting a crop all melons and vines left in the field should be collected and destroyed. If not done this refuse will breed swarms of the fly that will seek the products they infest in the surrounding district.

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FLEAS.

Several outbreaks of fleas have occurred in Honolulu during the year. The writer dealt with two cases in residences and succeeded in controlling the pests. In each instance the species was the common dog and cat flea (*Ctenocephalus canis*).[a] The determination is by Mr.

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[a] *Pulex serraticeps* is a synonym.

D. W. Coquillett, Bureau of Entomology, U. S. Department of Agriculture.

Mr. C. F. Baker gives the following in regard to the distribution and hosts of this species:

> The common cat and dog flea is probably the most widely distributed member of the order, occurring practically wherever cats and dogs occur. Doctor Lutz sends specimens from Brazil. It seems to be a normal and abundant parasite of cats and dogs, but has been found on a variety of other animals. It occurs commonly as a transient guest on almost all of the domesticated, semidomesticated, or caged animals, and will bite human beings whenever opportunity offers. Many reported cases of infestation of houses have been found to be due to this species, rather than to *Pulex irritans*. The case of a lot of fleas collected by Mr. Snyder from a fox at San Diego, Cal., offers a peculiar instance of unusual occurrence. A part of this lot proved to be *P. irritans* and the rest this species.[a]

The source of the fleas was traced to dogs about the dwellings, in one instance to homeless dogs that had taken up their abode beneath the house, and in the other to a dog belonging to the caretaker of the place. In the latter case when the family returned, after a considerable absence, they found the house, yard, and outbuildings infested with fleas. In and about Honolulu there are numbers of homeless dogs and cats that breed and distribute the pest wherever they roam.

Briefly the life cycle of the dog and cat flea is as follows: The eggs are laid loosely on the hairs of the dog or cat. These animals, when lying or walking around the place, leave behind innumerable eggs that become detached with the hairs in the persistent efforts of the animals to dislodge the adult fleas that are feeding on them. The eggs hatch and the larvæ develop in any place where the conditions of temperature and moisture are favorable. They feed during the larval period of life on whatever organic matter may be found in the places they occupy. These places may be in or beneath a rug or carpet in a house, in the dust of an unswept room, in crevices or joints of the underpinnings of the house, in the lawn beneath the grass, or in any of the outbuildings where the animals sleep.

In regard to the length of time necessary for development, Doctor Howard says:

> In the observations made at this Department upon this species of flea during the summer of 1895, some difficulty was found in preserving just the right degree of moisture to enable the insect successfully to transform. An excess of moisture was found prejudicial to the development of the species, as was too great dryness. The observations showed, however, that at Washington in summer an entire generation may develop in a little more than a fortnight. Hence

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[a] A Revision of American Siphonaptera. Proc. U. S. Nat. Museum, 27 (1904), p. 384.

a housekeeper shutting up her house in June, for example, with a colony of fleas too small to be noticed inside it, need not be surprised to find the establishment overrun when she opens it up again in September or October.[a]

The following remedial measures were recommended:

(1) If the lawn is infested, cut the grass as close to the ground as possible and burn the refuse. Exposure to the air and sun will be detrimental to the development of the larvæ. Keep the lawn well watered.

(2) Clean out and burn all refuse from beneath the infested dwelling, leaving the surface of the ground as bare as possible, and apply an even dressing over the surface of lime, sulphur, and buhach at the rate of 20 pounds of air-slaked lime to 3 pounds of powdered sulphur and 1 pound of buhach, thoroughly mixed and dry. Spray the underpinnings of the house, and the drives and walks (if the latter are sand, gravel, or dirt), with kerosene emulsion at the rate of 1 part of stock solution of the emulsion to 10 parts of water.

(3) If dogs are owned, provide a room for them to sleep in and keep cats out of the house. Wash with strong, hot soapsuds the floors of the room where the dogs are to sleep, and sprinkle afterwards, when dry, with a liberal amount of buhach. Use a liberal amount of buhach in places where the dogs have been in the habit of sleeping and remove and burn from such places all refuse, old sacks, matting, etc. Every week or so take the dogs to the room provided for them and brush them thoroughly with a strong stiff brush. Afterwards collect the resulting hairs and the bedding and burn or immerse the sacks in hot soapsuds and hang in the sun to dry. Then wash the room out as before and sprinkle with buhach and return the bedding. The dogs should be washed regularly, a little creolin being added to the water.

(4) If the house is infested, sprinkle a liberal amount of buhach beneath all rugs and matting and under all shelving and cabinets. The following day take all rugs, carpets, and matting out of doors and shake thoroughly and hang in the sun for several hours. Wash the floors with hot soapsuds. Sprinkle buhach beneath the rugs, carpets, and matting when returning them to the house.

In one case treated the fleas were so numerous that the men engaged in the work of destruction were with difficulty held to their job. Finally in desperation the writer purchased a quantity of "fly-paper" and wrapped the legs of the laborers in this (sticky side out). Several thousand adult fleas were captured in this manner in a day's work, and the workmen were thus afforded a measure of protection.

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[a] U. S. Dept. Agr., Div. Ent. Circ. 13. 2. ser., 1896, p. 4.

MOSQUITOES.

The top-minnows[a] introduced in 1905 to feed upon mosquito larvæ are established on all the principal islands. Areas of standing water are common in Hawaii and breed mosquitoes in immense numbers. (See Pl. I, fig. 1.) The following distribution of the fish has been made: Island of Oahu—Honolulu and vicinity generally, Aiea, Pearl City, Waialua, Maunawai, Wahiawa, and Waimanalo; island of Hawaii—Hilo and vicinity, and Paauhau; island of Maui—Kahului, Wailuku, and Lahaina; island of Kauai—Lihue, Eleele, and Waimea; and island of Molokai—Kalaupapa.

The history of the introduction of these fish has been summed up by the writer and published as Press Bulletin No. 20 of this station. It will be no longer necessary to breed the top-minnows for distribution, as the little fish swarm in several places where they have been liberated and can be obtained easily by those desiring to extend their distribution. This project is therefore completed. Hawaii has gained an addition to its fauna that will in future years many times repay the sum expended in the introduction and establishment of these natural enemies of mosquitoes.

The common Hawaiian mosquito, locally known as the "night" mosquito, previously reported by the writer as *Culex pipiens*[b] and by Mr. F. W. Terry as *C. fatigans*,[c] has been determined by Dr. H. G. Dyar as *C. cubensis*. One point of interest in regard to this species observed during the year is worthy of record. The larvæ have been found to breed in brackish water. To what extent can not be said without a careful survey. Waimanalo on the windward side of the island of Oahu has long been notorious as a mosquito-ridden place, and this is saying quite a little in Hawaii, where mosquitoes have been generally abundant. The main source of the mosquitoes was traced to a makai marsh, and an analysis of a sample of water from this marsh, taken at a place where mosquitoes of this species were breeding in immense numbers, gave 50 grains of salt to the gallon. (See Pl. I, fig. 2.)

In 1904 the writer pointed out the danger from yellow fever attending the establishment of a direct line of steamers between Hawaii and the Mexican coast and Panama.[d] The present discussion of this subject and its importance to the welfare of Hawaii leads the writer

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[a] The species introduced were *Molliensia latipinna*, *Fundulus grandis*, and *Gambusia affinis* of the family Pœciliidæ. These fish were collected and transported to Hawaii from Seabrook, near Galveston, Tex., by Mr. Alvin Seale.

[b] Hawaii Expt. Sta. Bul. 6, 1904, pp. 14–21.

[c] A Preliminary Account of the Insects of Economic Importance in the Hawaiian Islands (Diptera). Hawaiian Forester and Agr., 3 (1906), No. 2, pp. 36, 37.

[d] Hawaii Expt. Sta. Bul. 6, 1904, pp. 22, 23.

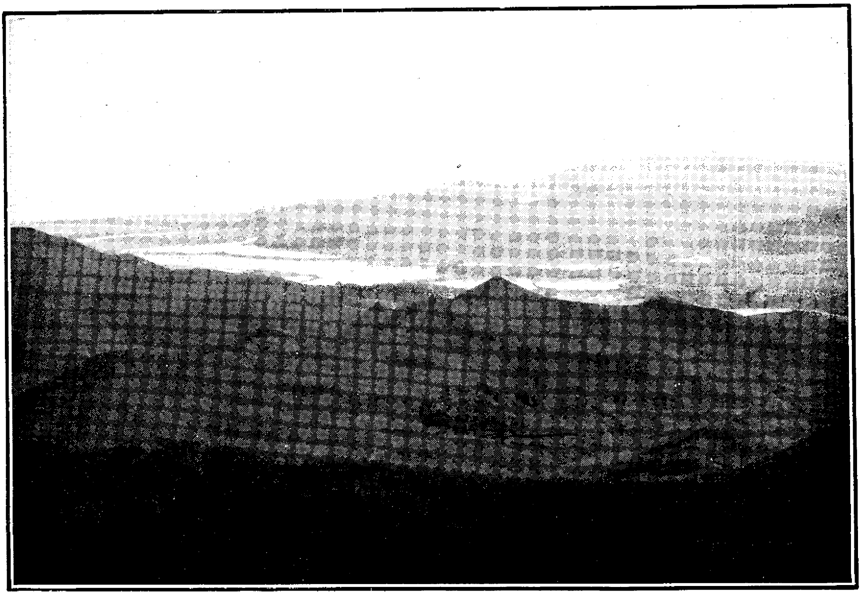

FIG. 1.—STANDING WATER FROM RICE AND TARO FIELDS WHERE MINNOWS HAVE BEEN SUCCESSFULLY INTRODUCED.

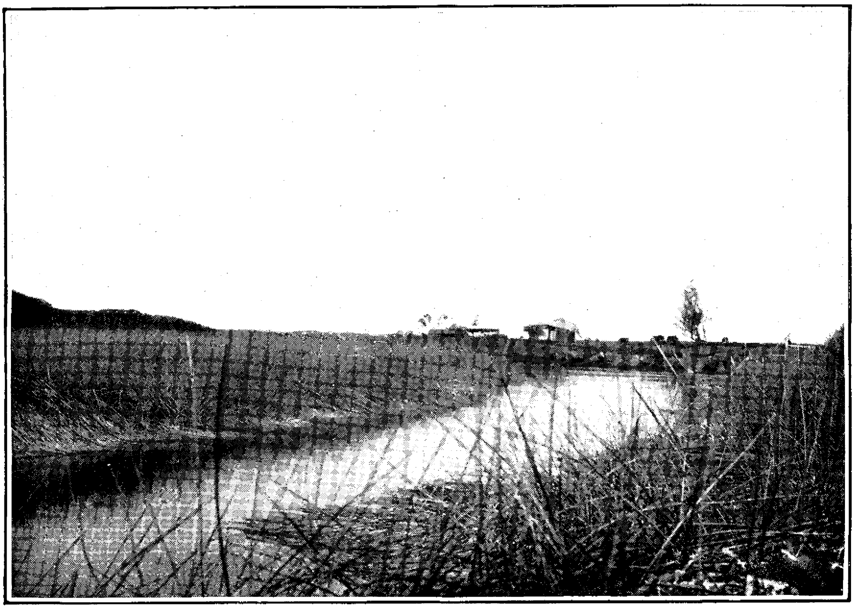

FIG. 2.—MARSH AT WAIMANALO, ON WINDWARD SIDE OF OAHU, WHERE FORMERLY MOSQUITOES BRED ABUNDANTLY.

to reprint here an article by Prof. V. L. Kellogg. The article is as follows:

> TO THE EDITOR OF SCIENCE: The continuous discussion of Panama Canal affairs suggests to me to call attention to the possibility that the cutting of the canal may lead to trouble from yellow fever in two of our Pacific island colonies. In the summer of 1902, spent in the Hawaiian and Samoan Islands as agent of the U. S. Bureau of Fisheries, my attention was forcibly called to the unusual proportions of the mosquito plague in both these island groups. If it were not for the dragon flies which wage effective war against the "day mosquitoes," and for the bed canopies of netting which protect the sleeper from "night mosquitoes," life would hardly be tolerable in Honolulu. In Tutuila (our principal Samoan island) mosquitoes are the most obvious features of the above-water fauna aside from the brown natives themselves. Now both in Hawaii and Samoa one of the most abundant of the infesting mosquito species is *Stegomyia fasciata*, which is none other than the yellow-fever mosquito, that is, the particular mosquito species which harbors and disseminates, in yellow fever regions, the plasmodium or bacterium which is the immediate cause of the disease.
>
> So far no cases of yellow fever have occurred in Hawaii or Samoa, but this is obviously not because of the absence of the yellow fever host, but, presumably, of the yellow fever specific causal agent, the pathogenic "germ." It is to be presumed that ships have not as yet carried yellow-fever-germ-infested specimens of Stegomyia from the West Indies to Hawaii or Samoa. Going around the Horn is probably an effective check to the spread of yellow fever from the West Indies to our Pacific Islands by reason both of the time required and the low temperatures met. Besides, there is little traffic now between the two regions. But with the cutting of the canal, making possible a direct short-time passage of ships from the Gulf of Mexico to Hawaii, or to Samoa, all of the voyage being within tropical or subtropical latitudes—the Hawaiian Islands are in 20° north latitude, the Samoan Islands in 14° south latitude—will there not be a real danger of planting the dread agent of yellow fever in our Pacific colonies in which already the necessary insect host exists in enormous numbers? There may be obvious reasons why this migration can not take place, but they are not apparent to me now. It is, at least, a contingency to be had in mind by those charged with the responsibility of public health affairs in Hawaii and Samoa.[a]

BEE KEEPING.

The principal line of work in bee keeping during the year has been the continuation and completion of the work on the source and characteristics of Hawaiian honeys, the assistant chemist of the station cooperating in a determination of the chemical composition of the same. This information has been prepared for publication as Bulletin No. 17 of this station. In all 54 samples of honey were collected and the source in each instance determined. Forty-nine of these samples were analyzed and a detailed study made of the two types represented—a floral honey and a honeydew honey.

The greatest value of this work has been its relation to marketing the Hawaiian product under the Federal Food and Drugs Act of June

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[a] Science, n. ser., 23 (1906), No. 577, p. 114.

30, 1906. The bulk of the Hawaiian honey is of a type that has been little studied and, for this reason, was not considered in the official definition of honey. The type is decidedly abnormal under the present official definition of honey and its abnormal characteristics are due to the presence of honeydew, a saccharine substance secreted by certain leaf-sucking insects or secreted by the plant itself from special organs. In Hawaii the honeydew is derived by the honeybee mainly from the secretions of the sugar-cane leaf hopper and the sugar-cane aphis on the leaves of the sugar cane.

The problem confronting the Hawaiian bee keepers was presented by the writer in person to the proper officials at Washington. While no modification of the official standard of honey was obtained, the results of the investigations on the Hawaiian product by this station have been accepted by the experts having the work in charge as satisfactory and conclusive.

The Hawaiian honeys, while somewhat abnormal in their ash content, are recognized as natural products and are not considered as adulterated in the usual meaning of that term. All honeys that polarize to the left, and this includes the pure algeroba honey and many of those made by bees from floral nectar and other substances, will be recognized as pure natural products and may be marketed as such. Those that polarize to the right are to be given a distinctive label, and as they are largely composed of honeydew, it is suggested that they be labeled " honeydew honey." A statement can accompany the label on the honeydew package which may read as follows: " This is a natural product containing no added glucose or other added sugars. It is unadulterated and is a product gathered and stored by the honeybee."

The writer would here express his appreciation of the careful and detailed consideration given the subject during his stay in Washington by Dr. E. F. Phillips, in charge of apicultural investigations, Bureau of Entomology, and Dr. C. A. Browne, in charge of the sugar laboratory, Bureau of Chemistry.

Two further projects relating to bee keeping have developed from the work on Hawaiian honey. They are (1) the introduction and establishment of bee plants to increase the floral product and improve the character of Hawaiian honey, and (2) the production of beeswax on a commercial scale. The writer spent two weeks in southern California on his return home from Washington and gave special attention to plants desirable to introduce into Hawaii for bee pasturage. White sage, black sage, two species of Phacelia and horehound, abundant nectar producers and suitable for dry waste lands, will be introduced during the coming year. A list of some twenty other plants was obtained and other introductions will be made. Some of the plants are valuable as forage, but others must be studied to learn whether or not there will be danger of their invading the pasture lands or cultivated areas. As regards wax production, wax is at present considered simply incidental to honey production. The writer believes it will be more profitable to Hawaiian bee keepers to increase the proportion of wax to honey and experiments will be undertaken with this in view. The experiments will include the feeding back of honey and modifications of the present methods of extraction and the use of foundation.

FOUL BROOD.

Neither European foul brood (*Bacillus alvei*) nor American foul brood (*B. larvæ*) has as yet become established in Hawaii. In order to prevent their introduction the Hawaiian Bee Keepers' Association was successful in obtaining the following legislation at the last session of the Territorial legislature:

AN ACT (ACT 69) To amend Chapter 28 of the Revised Laws of Hawaii by adding to said chapter a section to be known as Section 389A.

Be it enacted by the legislature of the Territory of Hawaii:

SECTION 1. Chapter 28 of the Revised Laws of Hawaii is hereby amended by adding a new section thereto to be known as Section 389A, and to read as follows:

"SECTION 389A. It shall be the duty of the board to make rules and regulations and to amend the same from time to time, in its discretion, subject to the approval of the governor, for and concerning the importation into the Territory of bees and for the preservation, protection, and improvement of bees now within the Territory, and for the quarantine, inspection, fumigation, disinfection, exclusion, or destruction, either upon importation into the Territory or at any time or place within the Territory, of any bees, and any box or other container and their contents in which bees have been imported or contained, which is or may be infested with or liable to assist in the transmission or dissemination of any insect or disease injurious to bees. All rules and regulations made as aforesaid shall have the force and effect of law. It shall be the duty of the board to establish an observational apiary, and all bees imported into the Territory shall be there quarantined, free of cost to the owners, until such time shall have elapsed as to enable the proper entomologist or inspector of the board to certify to the owners that such bees are clean and free from disease. The entomologists or inspectors of the board may enter upon the premises of any bee keeper for the purpose of inspecting the apiaries and of carrying out the orders of the board, and they shall not be holden guilty of any misdemeanor by so doing nor shall they be personally liable in damages, except for acts beyond the scope of their authority or due to their own negligence."

SEC. 2. This act shall take effect from and after the date of its approval.

Approved this 17th day of April, A. D. 1907.

G. R. CARTER,
Governor of the Territory of Hawaii.

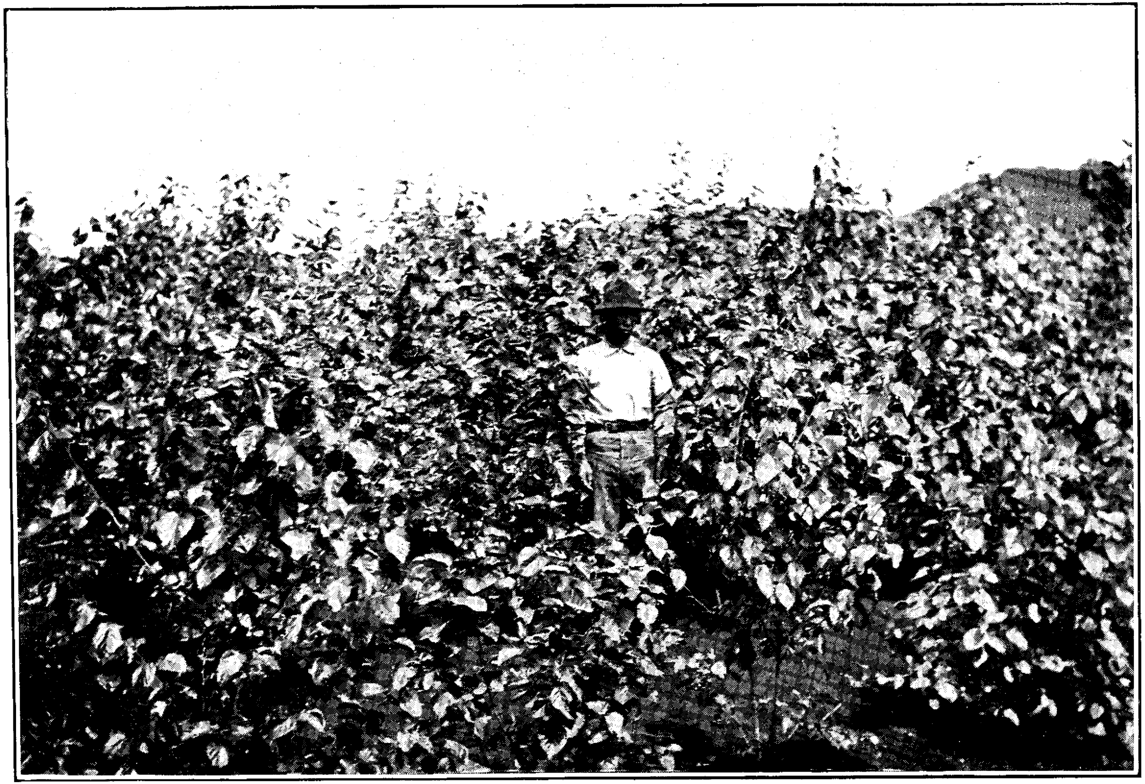
SILK CULTURE.

The investigations relating to the possibility of silk culture have progressed far enough to enable the writer to state definitely that silk of good quality can be produced with as little effort in Hawaii as in any silk-producing country. Three crops of cocoons have been grown, the details of which are given in the reports of the entomologist for 1905 and 1906, representing the Japanese white, the Chinese Oro yellow, and the Italian Sferici races, and these cocoons have been pronounced by the experts of the U. S. Department of Agriculture Bureau of Entomology "well worthy of being graded as first class." Doctor Howard also states that the economy in reeling "is equal to the most economical results obtained in experienced silk-producing countries." These results were obtained under abnormal and adverse conditions of food and equipment for growing the worms.

The 1906 experiments were all but ruined by a shortage of food at the most critical time, due to a drought that forced the mulberry trees into a semidormant state. The supply of mulberry leaves has heretofore been obtained from various trees and hedges growing in widely separated places in the city of Honolulu. To provide for future experiments and to obtain information on the culture of the mulberry for silk raising, a mulberry plantation has been established during the year. (See Pl. II.) This plantation is about 1 acre in extent, is provided with facilities and water for irrigation, and consists of 2,000 seedlings of *Morus alba*, received through Dr. L. O. Howard from the Bureau of Plant Industry.

Two systems of planting the mulberry have been tried. The seedlings were placed in orchard rows and in hedges. The plants in orchard rows will be allowed to grow to trees and will be pruned to produce the maximum amount of leaves. The hedges will be stripped of their leaves during feeding time and cut back after each picking. The extent that leaf production can be influenced by methods of culture and irrigation will be determined, together with the most profitable system of mulberry culture as regards labor for leaf picking. The project on silk culture will be limited during the coming year to the culture of the mulberry. The next experiment on the growing of cocoons will be undertaken on a more extended scale than heretofore; the abundant food supply close at hand will make this possible. If Hawaii is to succeed in holding the laboring class to the soil, the industry of silk culture is worthy of receiving serious consideration.

PLATE II.



MULBERRY SEEDLINGS TEN MONTHS FROM TIME OF PLANTING.

A PARTIAL LIST OF THE INJURIOUS INSECTS OF HAWAII, PART 4.

(Continued from the Annual Report of the Hawaii Agricultural Experiment Station for 1906.)

FIELD CROPS.

RICE.

A beetle (*Rhizopertha pusilla*) was bred from stored rice that has been introduced for seed. This species is recorded by Blackburn from the island of Oahu in 1885.[a]

The Angoumois grain moth (*Sitotroga cerealella*) has been bred in large numbers from stored rice during the past year. The moth infests both harvested rice and standing rice in the field. The pest has proved especially persistent in stored rice in the paddy, but has been successfully controlled at the station by carbon bisulphid. The fact that this pest can breed uninterruptedly throughout the year in Hawaii will necessitate prompt remedial measures when infestation occurs to prevent a heavy loss in weight.

In regard to a remedy, Chittenden says:[b]

> A limited number of insects, like the Angoumois grain moth in the extreme South, enter the grain in the field, and certain precautions are therefore necessary to prevent their access to the granary. This is accomplished (1) by harvesting as soon as the grain is ripe, and (2) by thrashing as soon afterwards as possible.
>
> In the process of thrashing or cleaning much infested grain is blown out with the chaff and dust, and the moths are killed by the agitation which the grain receives; but the immature forms of these insects, concealed in the kernels as eggs, larvæ, and pupæ, are apt to survive this treatment, and further measures are necessary for their destruction.
>
> For this purpose a quarantine bin is desirable, to be as nearly air-tight as possible, in which the newly thrashed as well as the infested or suspected grain can be fumigated with bisulphid of carbon. * * *
>
> Fresh grain should not be exposed to insect attack by being placed in bins with "weeviled" grain, or even housed under the same roof with such grain. If before storing in buildings that have been infested the old grain be removed, the bins thoroughly cleaned, floors, walls, and ceilings brushed and scrubbed, the chances of infestation will be reduced to a minimum. If the storehouse has been badly infested a fumigation with bisulphid is necessary.

SWEET POTATO.

The sweet-potato weevil (*Cylas formicarius*). (See pages 28–30.)

The sweet-potato sphinx moth (*Protoparce cingulata*). The caterpillar of this moth (*Sphinx convolvuli*) is recorded by Meyrick, in Fauna Hawaiiensis, in 1899, from the islands of Hawaii and Maui.

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[a] The determinations of the Coleoptera (beetles) recorded in this report were made by Mr. E. A. Schwarz, of the Bureau of Entomology, U. S. Department of Agriculture.

[b] U. S. Dept. Agr., Farmers' Bul. 45, pp. 19, 20.

The writer has collected specimens from the islands of Oahu and Molokai. The caterpillars are common on sweet-potato vines and *Ipomœa* spp.

The sweet-potato vine borer (*Omphisa anastomosalis*). The writer has not observed the work of this moth, but the species is recorded by Meyrick in Fauna Hawaiiensis in 1904. Mr. O. H. Swezey has observed the moth and the work of the caterpillars in sweet-potato vines and records his observations as follows:

> This Indo-Malayan moth was first recorded for Honolulu in 1904. Since then it has no doubt been on the increase, and may possibly before long become a garden pest, if not so already. During January, February, and March, 1906, I found the larvæ boring in vines of sweet potato in my garden. Of about half a dozen hills, all were found to be infested. The larvæ were found boring in the vines near the base, and hence just at the place to be the most injurious. Often two or more near together in the same vine, living upon the green, juicy pith of the stem. They probably do considerable boring in the potatoes also, as one was found in a potato from the market.[a]

The root maggot (*Pegomya fusciceps*) was collected on the island of Molokai during March, 1907. This insect pest is known commonly under various names, as the seed-corn maggot, the cabbage-root maggot, etc. Chittenden records the species as a pest of sweet potatoes.[b]

FRUIT CROPS.

PINEAPPLE.

The common mealy bug (*Pseudococcus citri*)[c] was recorded in the writer's report for 1904 as *Dactylopius* sp. The species is recorded by Kirkaldy in Fauna Hawaiiensis in 1902 from orange.

The pomace fly (*Drosophila ampelophila*). The determination of this fly was made by Mr. D. W. Coquillett, of the Bureau of Entomology, from specimens collected by the writer on July 19, 1906, found developing in ripe pineapples in canneries at Wahiawa, Oahu. This fly is common throughout the United States and particularly noticeable in the fall of the year about cider mills and wineries, about which it breeds in the pomace and refuse. No evidence of the work of the fly could be found in the field and apparently its injury is confined to the overripe and bruised pineapples in the cannery. Destruction of the waste about the cannery is an effective method of control.

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[a] Proc. Hawaiian Ent. Soc., 1 (1906), pt. 2, p. 76.

[b] U. S. Dept. Agr., Div. Ent. Bul. 43, 1903, p. 69.

[c] The determinations of the Coccidæ (scale insects) recorded in this report were made by Mr. J. G. Sanders, Bureau of Entomology, U. S. Department of Agriculture.

MANGO.

Trionymus americanus, a small mealy-bug-like coccid, was collected from the bark of the Bombay mango by Mr. Donald McIntyre at Moanalua, Oahu, during July, 1906.

Thrips (Thripidæ, undetermined). Thrips were first noticed on the leaves of mangoes during 1906 at Moanalua, Oahu. During the summer of 1907 the insect had increased to injurious numbers in this locality and specimens were recently collected and referred to the Bureau of Entomology for identification. The insect is causing serious injury to the young growth of the trees and on badly infested trees blemishes the surface of the developing fruit. The most effective remedy thus far has proved to be a spraying mixture of whale-oil soap and tobacco prepared as follows: Five pounds of waste tobacco was boiled in sufficient water to make about 1 gallon of strong decoction. Two pounds of whale-oil soap was dissolved in 1 gallon of boiling water and then mixed with the tobacco decoction. The mixture was diluted with 10 gallons of water and applied as a spray.

APPLE.

The following insects have been collected from apple trees: The Japanese beetle (*Adoretus umbrosus tenuimaculatus*) and the scale insect (*Pseudaonidia clavigera*), collected in September, 1906, from apple at Koloa, Kauai.

ORANGE.

The scale *Parlatoria ziziphus* was taken from orange in January, 1907.

BANANA.

The banana leaf-roller was recorded in the 1904 report of the writer as *Omiodes blackburni*. Mr. O. H. Swezey, in a recent bulletin of the Hawaiian Sugar Planters' Experiment Station,[a] distinguishes the species infesting the banana from the common *O. blackburni* found on palms and describes the species infesting the banana as new under the name of *O. meyricki*.

COCOANUT.

The following insects have been observed working on the cocoanut palm tree: The cane borer (*Sphenophorus obscurus*), the palm leaf-roller (*Omiodes blackburni*), and the Florida red scale (*Chrysomphalus ficus*).

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[a] Hawaiian Sugar Planters' Expt. Sta., Div. Ent. Bul. 5, pp. 24–27. (August, 1907.)

ORNAMENTAL PLANTS.

HIBISCUS.

Cosmophila sabulifera. The caterpillars of this moth were destructive to the foliage of hibiscus about Honolulu in one or two instances during the year. The moth was determined by Doctor Dyar, of the U. S. National Museum. The species is recorded by Meyrick in 1899 in Fauna Hawaiiensis, from Hawaii, Kauai, and Oahu.

PEPPER TREE.

The following scale insects have been collected during the year from the pepper tree: *Saissetia nigra* and *Aspidiotus lataniæ.*

ROSE.

The common aphis of the rose in Hawaii has been determined and recorded during the year as *Macrosiphum rosæ* by Mr. Kirkaldy.[a]

BAMBOO.

A scale insect (*Asterolecanium miliaris*) was collected from bamboo on Kauai in October, 1906.

FOREST TREES.

RUBBER (CEARA).

The following scale insects were collected from Ceara rubber during the year: *Aspidiotus cyanophylli* and *Saissetia oleæ.*

Wireworms, larvæ of a click beetle (Elateridæ, undetermined), did some damage to seeds in seed beds in Nahiku, Maui, at the beginning of the planting there. The seeds had been filed through at the ends, allowing entrance by the worms. The source of the wireworms was found to be horse manure used in preparing the seed beds, the manure offering a breeding place to the beetles.

A bark beetle (*Xyleborus affinis*) and a snout beetle (*Pseudolus longulus*) were found to infest this tree, their attack being in the unhealed wounds caused by repeated tapping.

ALGEROBA.

The scale insect (*Asterolecanium pustulans*) was taken during the year from the algeroba on the islands of Oahu, Kauai, and Molokai.

WILD GUAVA (WAIAWI).

A bark beetle (*Xyleborus affinis*), Kauai, and the scale insect (*Aspidiotus lataniæ*), also from Kauai.

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[a] Proc. Hawaiian Ent. Soc., 1 (1907), pt. 3, p. 100.

LIVE STOCK.

A considerable portion of the writer's time during the latter part of the year has been occupied in a study of the insects affecting live stock in Hawaii. The species affecting live stock that have been observed or are recorded from Hawaii will be briefly listed here, since a detailed report is in course of preparation.

CATTLE.

The horn fly (*Hæmatobia serrata*)[a] was probably introduced during 1897 and first recorded by Koebele in 1899. It also attacks sheep in Hawaii and to some extent horses.

The warble fly and the heel fly, *Hypoderma bovis* and *H. lineata.* One and possibly both of these flies have been brought to Hawaii with imported cattle from the western coast of the mainland. Neither species has apparently become established.

SHEEP.

The blow fly (*Calliphora dux*) occurs on the islands of Hawaii, Kauai, Oahu, and Molokai. This species is the abundant and injurious blow fly of the Hawaiian Islands.

The English bluebottle fly (*Lucilia serricata*). This animal parasite was taken in small numbers in company with the blow fly (*Calliphora dux*).

The American bluebottle fly (*L. cæsar*). This fly is recorded from the island of Hawaii by Grimshaw in Fauna Hawaiiensis in 1901.

The flesh flies (*Sarcophaga barbata* and *S. pallinervis*). Both of these species have been bred from dead animal tissue and would probably attack wounds in live stock.

The sheep bot fly or head maggot (*Œstrus ovis*). Recorded by Grimshaw in Fauna Hawaiiensis in 1901 from the island of Kauai.

The screw worm (*Compsomyia macellaria*). Reported from the island of Niihau during 1905.

HORSES.

The stable fly (*Stomoxys calcitrans*).

The horse bot fly (*Gastrophilus equi*).

The horse chin fly (*G. nasalis*).

The "night" mosquito (*Culex cubensis*).

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[a] The determinations of the Diptera (flies) mentioned in this report were made by Mr. D. W. Coquillett, of the Bureau of Entomology, U. S. Department of Agriculture.

POULTRY.

Lice, undetermined.
Mites, undetermined.
The "night" mosquito (*C. cubensis*).

DOGS.

The dog flea (*Ctenocephalus canis*) (see page 35), the dog tick (*Rhipicephalus sanguineus*), and the "night" mosquito (*C. cubensis*).

STORED PRODUCTS.

A beetle (*Silvanus mercator*) was bred during the year from crackers and a prepared "breakfast food."

The ham and cheese maggot (*Piophila casei*) was collected during the year on the island of Molokai.

The cadelle (*Tenebroides mauritanica*) was bred in immense numbers from horse feed (rolled barley) in August, 1907.

A beetle (*Aræocerus fasciculatus*) was bred from the seeds of St. John's bread (*Ceratonia siliqua*) received from Kohala, island of Hawaii. This same beetle was bred from cotton bolls received from Kona, island of Hawaii.

A weevil (*Calandra linearis*) was bred from imported seeds of the sweet tamarind. Blackburn records *C. linearis striata* in 1885 as "plentiful in decaying tamarinds, near Honolulu."

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(Continued from Report of the Entomologist, Annual Report of the Hawaii Agricultural Experiment Station for 1906, pp. 31, 32.)

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REPORT OF THE HORTICULTURIST.

By J. EDGAR HIGGINS.

The chief work of the year in the horticultural division has consisted in experiments in the shipping of tropical fruits. The horticulturist sailed from Honolulu August 1, 1906, accompanying a shipment of fruits composed of pineapples, avocados, papaias, and bananas. Arriving at San Francisco August 7, the whole shipment of fruit, except the bananas, was transferred immediately to express cars and taken to Portland, Oreg. From this point the fruit was distributed to Astoria, Tacoma, Seattle, and Vancouver, British Columbia. The results of these experiments, so far as the possibility of fruit shipping is concerned, and the methods best suited to shipping are embodied in a bulletin of this station.[a] It may be said here, however, that the experiments led to the belief that it is perfectly feasible to ship avocados and papaias to any market on the Pacific coast which can be reached by a direct journey; and pineapples and bananas may be shipped much farther. A large portion of the shipment, even of papaias and avocados, arrived in Portland in good condition, and specimens of each of these were taken to all the points mentioned. Specimen packages of pineapples were successfully shipped from Portland to the governors and the mayors of cities in all the chief mountain States.

The following letter from Governor Gooding, of Idaho, and the excerpt from a letter of Mr. G. B. Dennis, chairman of the publicity committee of the Chamber of Commerce of Spokane, Wash., will indicate something of the condition in which these fruits arrived, and the market which they would find in any part of this region.

STATE OF IDAHO, EXECUTIVE OFFICE,
Boise, Idaho, August 31, 1906.

JARED G. SMITH, *Special Agent Hawaii Experiment Station,*
U. S. Department of Agriculture, Honolulu, Hawaii.

MY DEAR SIR: Your crate of fruit, which you very kindly sent me, was received about two days ago in the very finest possible condition. I want to thank you and the Hawaii promotion committee for your kindness, and to assure you that if you are able to deliver as fine fruit as this there should be no difficulty in securing a market throughout the United States for your product.

I have the honor to remain yours, very truly,

F. R. GOODING, *Governor.*

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[a] Hawaii Sta. Bul. 14.

SPOKANE, WASH., *August 24, 1906.*

Mr. JARED G. SMITH,
Special Agent in Charge, Hawaii Experiment Station, Honolulu, T. H.

DEAR SIR: I am the recipient of your twofold compliment—your letter of July 26, and the crate of pineapples received by express the day before, and assure you that I accept the compliments of the Hawaii Experiment Station and the Hawaii promotion committee very gratefully.

The pineapples were received in perfect condition, there not being a single blemish anywhere on any of them. It was my pleasure to eat one of them, and to distribute the other five among the members of my committee, all of whom gave high praise to the delicious taste and flavor of the fruit. I personally have no hesitancy in stating that these features of the fruit, as well as that of size, exceed those of the fruit that we are used to receive here from southern California, Mexico, and Florida, and there should be no reason why the Hawaiian Islands should not command this trade with this northwestern section of the United States.

Very truly yours,

G. B. DENNIS,
Chairman, Publicity Committee, Chamber of Commerce.

The Pacific Northwest is a market which Hawaiian fruit growers should seek to develop. With the direct communication which is bound to come sooner or later this will be one of our nearest markets. It is also the most remote market in the United States from the standpoint of Hawaii's competitors in tropical fruit growing in Florida, the West Indies, and Central America. It is so situated that from these points a long haul by rail is unavoidable. Hawaii even at the present time can reach this market by water route exclusively. The Pacific Northwest has a large and growing population. There is probably no part of the United States which is making as rapid strides in prosperity and in increase of a desirable class of population. The three cities of Portland, Seattle, and Tacoma in themselves represent nearly half a million people of a class that can afford to spend money freely for Hawaiian fruits. The whole surrounding country tributary to these cities is rich in agriculture, lumbering, and other resources, and is destined to become the center of a very large population. The same may be said of Western Canada, toward which the streams of population have been flowing rapidly for several years. Both these great sections of country, while rich in agricultural resources, can not grow either tropical or even subtropical fruits, and therefore offer a most inviting field for the sale of Hawaiian fruits.

This is emphatically the time to get into these markets and gain a foothold before competitors become so firmly established as to make entrance difficult for the Hawaiian growers.

ORCHARD AND OTHER FRUITS.

During the year the orchard area has been increased by the planting of about 4 or 5 acres. The first planting of avocados has made an excellent growth and should come into bearing in about two years hence. The orchard has been increased in area. A planting of mangoes, consisting of several hundred trees, some of which are inarched and others of which are to be budded, adjoins the orchard of avocados. The other newer plantings in orchard form consist of the following: Oranges (Pl. III, fig. 1), pomelos, lemons, papaias, sweet sop (*Anona squamosa*), sour sop (*A. muricata*), cherimoya (*A. cherimolia*), Kafir plum (*Harpephyllum caffrum*), *Spondius lutea*, guava (*Psidium guajava*), in several varieties, and the star apple (*Chrysophyllum cainito*). About 1 acre has been planted to mulberries, for experiments in the production of food for silkworms, in cooperation with the entomologist.

THE STAR APPLE.

The star apple (*Chrysophyllum cainito*) (Pl. III, fig. 2) is a fruit worthy of much wider cultivation than it receives. There are, in fact, comparatively few specimens of this tree in Hawaii, but sufficient have been grown to show its possibilities. It makes a strong growth, attaining a height of about 25 feet, and is one of the most beautiful fruit trees of small size, the under surface of the leaves being of a rich golden hue. The fruit is about the size of an apple, and when cut in cross sections shows the carpels so arranged as to simulate a star, thus giving the common name to the species. The fruit is globular in form and smooth, varying in color from green to purple. The pulp is of delicious flavor and pleasing texture and should place this fruit with the mangosteen in quality. All the varieties grown in Hawaii are seedlings, but it is highly probable that the tree could be propagated by budding or grafting, and thus perpetuate individual characters of the best varieties.

A few specimens of the star apple have already been planted in the station orchards and are prospering. About 150 seedlings are in the propagating houses and will be set in the orchard and distributed to local growers.

THE ANONA GROUP.

Several species of Anona are found in the gardens of a few cultivators in Hawaii, and at least one species, the cherimoya (*Anona cherimolia*), is found practically wild in Kona, Hawaii, where it has escaped from cultivation. The finer varieties of cherimoya are among the most highly prized of tropical fruits. These are propagated by grafting. The fruit weighs from 3 to 8 pounds, or even as high as

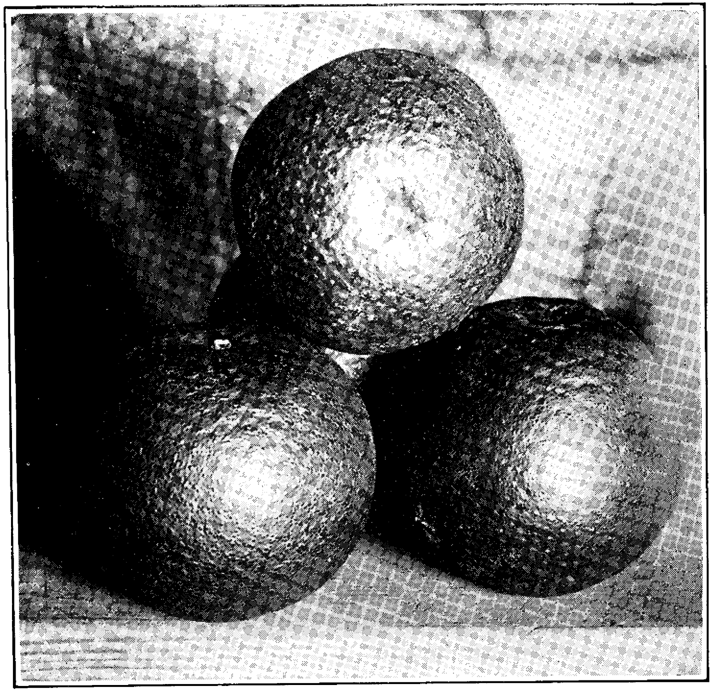

FIG. 1.—AN UNNAMED HAWAIIAN SEEDLING ORANGE.

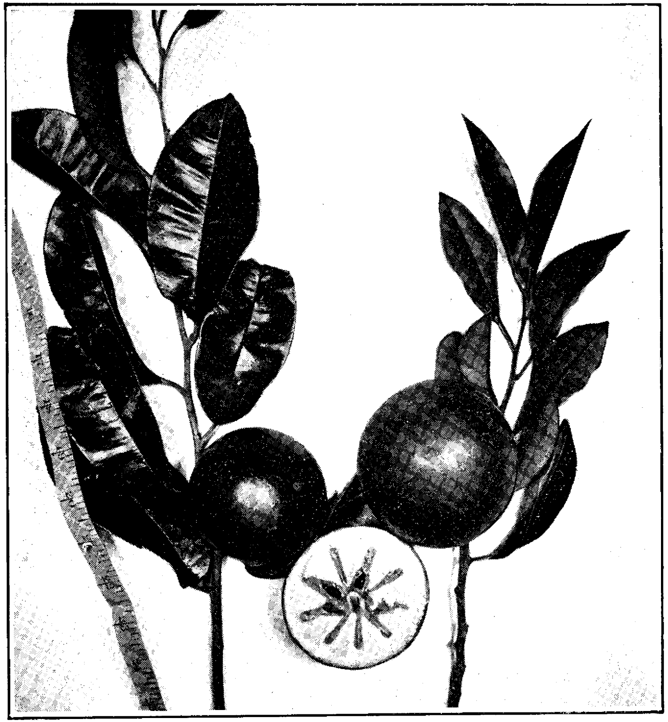

FIG. 2.—THE STAR APPLE (CHRYSOPHYLLUM CAINITO).

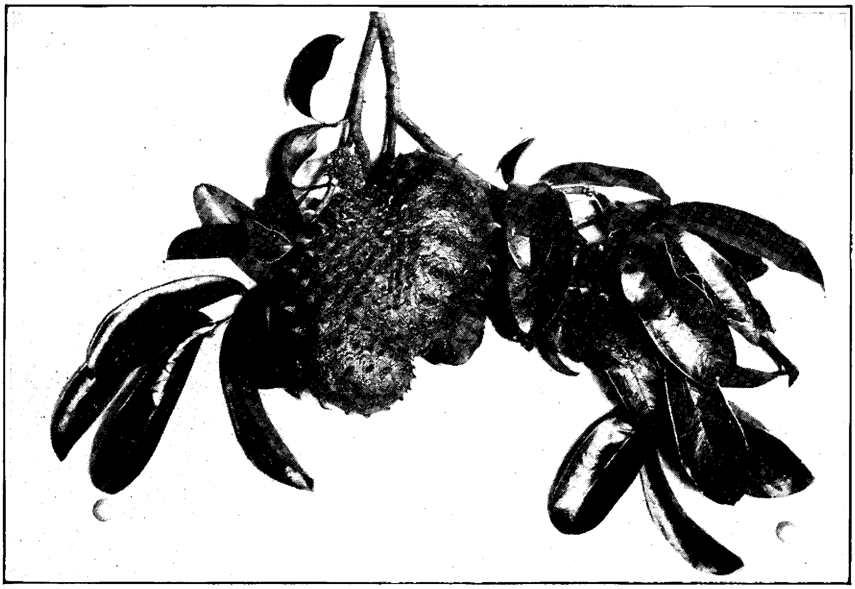

FIG. 1.—THE SOUR SOP (ANONA MURICATA).

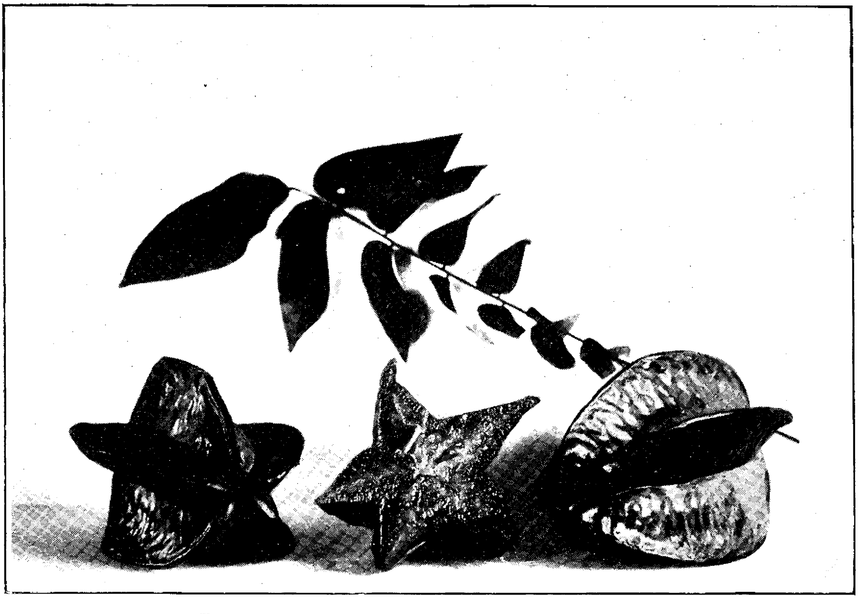

FIG. 2.—THE CARAMBOLA (AVERRHOA CARAMBOLA).

16. Those of ordinary size are reported to sell in the London market at $1.50 each, and the very large ones as high as $2.50 and even $3. This fruit is regularly cultivated in Madeira, and has replaced the grapevine in some parts of the island. From the luxuriant growth which the semiwild plants have made on the slopes of Kona, there is every reason to believe that, with the direct communication between Kona and the mainland which is likely to be inaugurated in the not distant future, the finer varieties of this fruit could be made highly profitable in cultivation. In the sheltered spots at some elevations on the island of Oahu this fruit could probably be grown and marketed in San Francisco. It is said to be a fairly good shipper. The station has already secured a few specimens of valuable varieties of cherimoya. The sweet sop (*A. squamosa*) should also be cultivated more extensively than at present, at least for home consumption. It is a very delicious fruit, though somewhat smaller than the cherimoya. The white flesh surrounds the large black seeds, but is easily separable from them. In form the fruit is heart shaped with an exterior divided into many segments. The sour sop (*A. muricata*) (Pl. IV, fig. 1) is perhaps the most vigorous stock of the Anonas in Honolulu. It appears to be better adapted to low elevations than some of the other members of the group. The fruit is not so universally appreciated as the cherimoya or the sweet sop, but is much liked by some, and is more commonly seen in the market in Honolulu than any other Anona. The pulp is eaten raw or may be used in sherbets.

THE CARAMBOLA.

The carambola (*Averrhoa carambola*) is a Chinese fruit of considerable value. The tree is of beautiful foliage and attains a height of about 20 feet. The fruits are produced abundantly and with their unique form and attractive coloring add much to the beauty of the tree. These fruits (Pl. IV, fig. 2) are deep lobed and star shaped in cross section. They contain an abundance of juice, which may be used in the making of a drink similar to lemonade. There is an acid and also a sweet variety. The station has about 150 seedlings of this also, which will be distributed in part and in part planted in the station orchard.

CARICA QUERCIFOLIA.

This species of Carica is said to be much richer in papaine, or "vegetable pepsin," than the papaia. Several trees of this species have been grown on the station trial grounds and have made a vigorous growth and produced their small fruits abundantly. No tests have been made of the papaine content. The fruits have a slightly acid taste not found in the papaia, offering an interesting field for crossbreeding.

THE ROSELLE.

The cultivation of the roselle (*Hibiscus sabdariffa*) has been continued during the year. In November and December most of the crop was harvested.

This plant was first introduced in Hawaii from Australia, so far as the writer is informed, by Mr. R. A. Jordan. A supply of seeds was secured by the experiment station from Porto Rico in 1904 and the plants have been grown on a field scale for two years. It gives promise of being a very useful plant.

The fruit of this plant consists of a fleshy calyx and a seed pod which are used in the making of jam, jelly, and a cooling drink. The flavor is tart and, if not obscured by the use of an excessive amount of sugar, resembles closely that of cranberries. In color and general appearance both the jam and the jelly are very attractive. The following directions for the manufacture of jam have been used in experiments conducted by Miss Alice R. Thompson, of this station. The data will also show the quantity of jam or of jelly which can be produced from a given number of pounds of fruit. These experiments were conducted with fruit that was rather overmature and the seed pod was too ripe to be used. When fruits are young the whole of the fruit may be used.

Roselle jam.—Wash 6 pounds of roselles, open and remove the seed pod. The weight of flesh will be about 3 pounds. Add 2 cups of water to the berries and cook about an hour until reduced to a soft pulp. Measure the cooked fruit and add 1¼ cups of sugar to each cup of fruit. Cook twenty minutes.

Six pounds of roselles will make 7 pounds of jam or 11 half-pint cupfuls.

Roselle jelly.—Wash and seed 4 pounds of roselles. The weight of the flesh will be about 2 pounds. Add 4 cups of hot water and boil to a pulp. Strain the whole through a cloth bag without pressing. Measure the juice and boil it continuously twenty minutes. Then add 1 cup of sugar for each cup of juice. The sugar should be heated in the oven before adding it to the juice, so that the boiling will not be interrupted. Cook until, on testing the consistency of the liquid by pouring from a spoon, the last drop adheres to the spoon. Remove from the fire and pour into the jars. Four pounds of roselles will make 2 pounds of jelly or 2 half-pint cupfuls.

Cultivation of roselle.—It is best to plant the seeds in boxes or seed beds about the last of February or the first of March in Honolulu and transplant to the open field when the plants have attained a height of 6 or 8 inches. From the experience of the last two years at the station, there appears to be nothing gained by planting seed earlier than February. Seed planted before this date has produced plants which have borne prematurely and have not produced the main crop earlier than those from seed planted later. The plants should stand about 3 to 4 feet apart in the row and the rows from 4 to 6 feet apart. If the soil is good and moisture abundant, 4 by 6 feet will not be too great a distance.

The soil for the roselle need not, however, be the richest, but good soil will yield correspondingly good results. The harvest comes on about November and December in Honolulu. It is quite possible that in other parts of the islands other seasons for planting may be found preferable and the crop may mature earlier or later.

The after cultivation will consist only in keeping the soil well tilled and supplied with moisture.

The yields in the experiments conducted at the station would average from 6,000 to 7,000 pounds per acre with a very moderate use of water. The cost of picking these fruits would be from ½ to ¾ of a cent a pound. At 4 cents per pound net to the grower, these fruits could be placed on the market at a price very much lower than cranberries. Allowing ¾ of a cent for the cost of gathering and ¼ of a cent for packing materials, there would remain 3 cents per pound as the value of the fruit on the plants. These at 6,000 pounds per acre would represent a value of $180 per acre for the crop in the field.

THE NATAL PINEAPPLE.

Specimen plants of the "Natal pineapple," S. P. I. No. 8634, were received and planted August 9, 1905. These plants have fruited during May and June. The aim of the U. S. Department of Agriculture in introducing this fruit has been to place upon the market a fruit of unusual quality in very small size so that they could be served one at each plate. The fruit is small, of very fine color, aroma, and exquisite flavor. No points of difference, however, could be distinguished between this and the Queen variety. They appear to be the same fruit under two different names. This fruit would not be well adapted to canning, but might be desirable for some of the fresh fruit markets where a small fruit is demanded. The Queen is not commercially planted in Hawaii at present, many plants having been destroyed. The Smooth Cayenne has given better results on the island of Oahu, where the largest pineapple plantations are located. This is no doubt due chiefly to its large size and heavy yields. The Red Spanish has found favor in Kona on the island of Hawaii.

GRAPES.

Quite a large number of varieties of grapevines were introduced during the last year, and were placed in charge of a vineyard company on the island of Maui. Some of these varieties are reported to have done unusually well and give promise of being a more profitable vine than those now common in the islands.

MANILA HEMP.

The Manila hemp plant was introduced into Hawaii many years ago, but so far as known to the writer has never been grown on a commercial scale. Seeds of this species were obtained by the station several years ago from which quite a number of plants were grown. These have made a more vigorous growth than any other species or variety of the genus Musa on the experiment station lands. There are many steep gulches in the islands where the Manila hemp might be grown and, judging from the progress which these trial specimens have made, should prove very profitable as a source of the much-prized rope fiber of commerce.

PLANTINGS ON THE HIGHER ELEVATIONS OF THE STATION LAND.

About 2 or 3 acres, at an elevation of approximately 1,000 feet, have been cleared during the year and planted to peaches, figs, oranges, lemons, pomelos, loquats, mulberries, grapes, and strawberries. A small planting of papaias and of citrus stocks for budding occupies part of this area. The coffee and most of the other plants at this elevation which have been set out in previous years are making satisfactory progress. The avocados on this land, which were planted many years before the station was established, are an interesting field for study in the causes of barrenness and also of lack of quality in the fruit. Some of the trees have refused to bear, while others have produced very indifferent fruits. These characters may be inherent in the trees or may be in part due to uncongenial environment. This elevation may approach the limit for the production of the best fruit. The effect of liberal fertilizing is being tried on some of these trees.

DECIDUOUS PLANTINGS.

The horticulturist superintended the planting of about 6 acres of deciduous orchards on lands belonging to the Parker ranch on the island of Hawaii, at elevations varying from 2,700 to 5,000 feet. These consisted of the following: 125 apples, 100 pears, 100 cherries, 100 apricots, 10 almonds, 10 walnuts, 100 plums, 100 peaches, 10 figs, 5 oranges, and 5 lemons.

A few apple trees, which were planted at about 4,000 feet altitude several years ago, have made a very fine growth and were well supplied with fruit buds at the time when the last plantings were made. This is mentioned here as of considerable interest, being perhaps the largest mixed planting of deciduous fruits that has been made in the islands.

DISTRIBUTION OF SEEDS AND PLANTS.

The distribution of seeds and plants has come to be a very considerable factor in our work. The station can in this way be of direct assistance to many. The aim has been to distribute such species and varieties as are not readily obtainable elsewhere. The miscellaneous distribution of ordinary vegetable and flower seeds has not been encouraged.

The request for varieties of bananas from the station collection has exceeded the supply in all varieties except the Jamaica or Bluefields. There have been requests from many parts of the Tropics for specimens of the Hawaiian bananas and to such a degree that it has been necessary to suspend further distribution during part of the year.

The number of visitors at the station who wish to look through the grounds and propagating houses has increased greatly during the year. Instruction in methods of cultivation has thus been given verbally and by demonstration, including such subjects as budding, grafting, pruning, etc. In some cases it has been necessary for the horticulturist to visit the grounds of the inquirer.

HORTICULTURAL EXHIBIT.

In December, 1906, the station cooperated with the Hawaiian Poultry Association in a public exhibition held in Honolulu. The horticulturist gave considerable time to the collection and arrangement of specimens for this exhibit. Though not a good season for an exhibit of horticultural products, by the cooperation of many interested parties a creditable collection of specimens was brought together. This fair had certainly considerable educational value, and arrangements have been made for another exhibit during the coming season.

The horticultural exhibit on the part of the station consisted chiefly in fruit packages, illustrative of methods of packing used in fruit-shipping experiments of the preceding season. The roselle was also shown in quantity and attracted much attention as a new fruit worthy of cultivation.

THE NEED OF ASSISTANCE.

The work of the propagating houses and the experimental plats and orchards has greatly increased, demanding constant and careful attention. With the other work that has been done it has been impossible to devote as much time to this as it requires. During the past year the horticulturist has been absent from the station on official duty about three months, a considerable portion of which was spent on the mainland of the United States.

The need of an assistant has been recognized for a long time, and only the lack of sufficient financial resources has prevented the securing of aid. It is expected that a man can be secured during the next few months. This should add greatly to the efficiency of the work.

REPORT OF THE ASSISTANT CHEMIST.

By Miss Alice R. Thompson.

During the past year a large number of miscellaneous analyses were made, among them 49 samples of Hawaiian honey, special attention being given to the honeydew honey; 13 samples of fertilizers were analyzed for the fertilizer experiments carried on with rice by Mr. F. G. Krauss; 10 samples of soils of different origin; several salt determinations of waters and soils, and about 40 samples of fodders and feeding stuffs. The analyses of the honey samples are reported in a bulletin of the station.[a] The other analyses, except the fertilizers, are given in the accompanying tables.

ANALYSES OF HAWAIIAN SOILS.

Ten samples of soils were received and analyzed and the analyses are as follows:

Analyses of samples of Hawaiian soils.

Number of sample.	Moisture.	Organic matter and combined water.	Nitrogen.	Phosphoric acid.	Potash.	Lime.	Magnesia.	Manganese oxid.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	10.980	28.242	1.036	0.191	0.132	1.995	3.376	0.225
2	10.707	25.499	.840	.159	.145	1.880	3.687	.185
3	7.309	16.942	.313	.172	.361	.27	.608	.37
4	6.629	17.914	.238	.264	.515	.275	.535	.105
5	8.435	9.253	.232	.436	.324	1.470	1.575	.070
6	10.466	18.100	.477	.322	.126	1.135	1.838	.075
7	10.568	18.667	.435	.102	.331	.480	.835	.075
8	8.222	17.091	.336	.045	.339	.275	.559	.160
9	8.028	18.907	.273	.146	.283	.130	.711	.105
10	8.786	10.224	.153	.275	.659	.995	3.500	.20

Samples 1 and 2 were taken at Olaa, Hawaii. Both are brown sandy soils and acid in reaction with litmus paper, in spite of the amount of lime present, as shown by analysis. The potash content is low. Soil No. 1 has produced some sugar cane. Soil No. 2 is from coffee land.

Samples 3 and 4 were taken from pineapple land on Kauai. The pineapples growing on the soil were troubled with root disease. Both soils are brown loams and they react acid with litmus. Analysis shows a deficiency of lime in the soils.

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[a] Hawaii Sta. Bul. 17.

Sample 5 is soil from the rice fields at the experiment station trial grounds. The soil is a gray loam, is not acid, and contains but a trace of chlorin.

Samples 6 and 7 were taken at Keanae, Maui. Sample 6 is a dark sandy soil, acid in reaction, and containing a trace of salt. Analysis shows a deficiency of potash.

Sample 7 is a brown sandy soil, also acid in reaction. Analysis shows a deficiency of lime.

Samples 8 and 9 are from Hanapepe, Kauai. Pineapples are raised on this soil. Both soils are brown loams and acid. The lime content is low in both. Phosphoric acid is low in No. 8.

Sample 10 was taken at Kaimuku. The soil is a red clay loam.

SALT DETERMINATION IN WATERS AND SOILS.

Mr. J. P. Colburn sent to the station for salt determination three samples of water from wells to be used in irrigating rice fields. Sample No. 1 contained 129.41 grains per gallon, No. 2 contained 74.53 grains, and No. 3 contained 113.83 grains.

To determine the amount of salt tolerated by rice Mr. F. G. Krauss, rice expert, brought two samples of water from rice fields for analysis. Sample No. 1, water in which rice grew well, showed a salt content of 1.69 grains to the gallon. Sample No. 2, from a rice field in which only rice of an inferior quality grows, contained 56.915 grains per gallon. The rice field from which the latter sample was obtained comes in contact with tide water.

From these results it would seem that rice fields irrigated with water containing 74.53 grains per gallon could produce rice of inferior quality. Mr. Colburn's sample No. 1 indicates a water of even higher salt content, which even rice of inferior quality would scarcely tolerate.

Another sample of irrigation water was submitted and on analysis was found to contain 9.316 grains of salt per gallon.

The salt content of four samples of soil was later determined. These samples were selected by Mr. F. G. Krauss from rice fields in which the salt content varied. The samples upon analysis were found to contain 0.00556, 0.00092, 0.00037, and 0.00002 gram of sodium chlorid per gram of sample. The first three samples were taken from Waikiki rice fields and the fourth sample was from the station's trial grounds near Waikiki. In the first soil rice does not grow, in the second it barely survives, while in the third soil it grows well.

COMPOSITION OF HAWAIIAN FEEDING STUFFS.

The analysis of fodders has continued to be part of the routine work to the laboratory. Forty samples have been analyzed, the methods used being those adopted by the Association of Official Agricultural Chemists. Reference may be made to Bulletin No. 13 of this station, which contains the analyses of a number of Hawaiian feeding stuffs, the present report being a continuation of the work as set forth there.

The composition of the fodders analyzed is as follows:

Composition of Hawaiian feeding stuffs.

Kind of feeding stuff.	Proximate constituents.						Ash constituents.		
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Lime.	Phosphoric acid.
NONSACCHARINE AND SACCHARINE FORAGE.									
Sorghum:	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Per ct.*
Sample No. 1	75.11	1.71	1.76	13.56	5.45	2.41	0.31	0.12	0.09
Sample No. 2	78.92	1.38	.34	11.67	5.59	2.10	.27	.10	.09
Sample No. 3	62.79	2.53	.74	22.03	8.54	3.37	......	.19	.25
Average	72.27	1.87	.94	15.75	6.52	2.62	.29	.13	.14
Sorghum silage	76.76	2.04	.73	12.62	5.68	2.17	.38	.08	.13
Corn cut for silo	76.45	1.64	.24	12.67	6.43	2.57	.33	.08	.12
Corn silage	81.63	2.06	.31	6.61	4.35	5.04	.48	.16	.09
Millet roots (*Sorghum halepense*), air dried	11.18	7.22	.39	27.56	40.82	12.83	2.60	.06	.19
GRASSES.									
Hilo grass (*Paspalum conjugatum*):[a]									
Sample No. 1	70.48	1.52	.40	16.43	9.44	1.73	.40	.19	.06
Sample No. 2	71.70	1.43	.54	15.18	9.39	1.76	.43	.15	.06
Sample No. 3	78.20	1.38	.86	14.02	9.05	1.49	.37	.18	.06
Average	71.79	1.44	.60	15.21	9.29	1.66	.40	.17	.06
Rhodes grass (*Chloris gayana*):[b]									
Sample No. 1	64.78	2.81	.52	16.08	12.52	3.26	.50	.26	.16
Sample No. 2 (air dried)	10.87	9.00	1.53	38.05	27.36	13.19	1.31	.71	.95
Pili grass (*Heteropogon contortus*)[c]	66.93	2.05	.44	15.43	11.79	3.36	.44	.08	.13
Redtop (*Tricholæna rosea*), air dried	8.84	3.38	1.21	45.14	35.48	5.95	.59	.33	.28
Paspalum dilatatum[d]	72.95	1.96	.72	13.38	8.86	2.13	.52	.20	.12
Para grass (*Panicum molle*):[e]									
Sample No. 1	72.18	3.46	1.33	11.04	7.65	4.34	......	.16	.24
Sample No. 2	72.10	1.43	.29	13.31	11.19	1.68	.08	.09	.12
Side oats grama (*Bouteloua curtipendula*)[f]	39.47	6.43	1.05	27.68	18.12	7.25	.71	.21	.27
English and Italian rye grass (*Lolium perenne* and *L. italicum*)[g]	27.44	6.49	1.43	36.68	20.94	7.02	1.86	.44	.41
Wheat hay (containing a little oats)[h]	11.91	7.96	.94	38.27	30.09	10.83	3.31	.20	1.03
Rice straw[i]	10.89	4.81	2.67	36.91	24.84	19.88	......	.39	.41

[a] From Parker ranch, No. 1 below Baker's, No. 2 from Waihaka, and No. 3 at Baker's.

[b] No. 1 from Molokai ranch, 800 feet; No. 2 from Parker ranch.

[c] From Molokai ranch, 700 feet.

[d] From Molokai ranch.

[e] No. 1 from Waikiki, Oahu; No. 2 from Olaa.

[f] Grown at the experiment station, Oahu.

[g] From Parker ranch.

[h] From Waimea.

[i] Grown at Waikiki, Oahu.

Composition of Hawaiian feeding stuffs—Continued.

Kind of feeding stuff.	Proximate constituents.						Ash constituents.		
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Lime.	Phosphoric acid.
LEGUMINOUS FORAGE CROPS.									
Alfalfa:[a]	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Per ct.*
Sample No. 1	76.61	6.78	0.77	8.73	4.24	2.87	0.98	0.39	0.21
Sample No. 2	73.83	5.25	.76	11.21	5.56	3.39	1.00	.35	.23
Sample No. 3	72.18	8.00	.72	9.44	6.27	3.39	....	.50	.22
Average	74.20	6.67	.75	9.79	5.35	3.21	.99	.41	.22
Cowpea (*Vigna sandwichensis*)[b]	82.35	3.06	.58	7.24	4.22	2.55	.62	.34	.14
ROOTS USED AS FORAGE.									
Cassava refuse from crude extract of starch	15.46	1.21	.10	76.93	5.45	.85	.314	.17	.04
Cassava waste (first washing for starch manufacture)	16.30	1.31	.22	79.82	1.08	1.27	.08	.10	.08
Taro waste	70.73	.36	.24	27.25	.89	4.36	.13	.05	.07
Tacca pinnatifida	66.80	1.93	.12	29.64	.58	.84	.39	.06	.07
Ti root	46.78	3.76	.16	42.28	5.40	1.62	.27	.56	.09
Beet, Yellow Tankard	94.12	1.00	.04	2.62	.97	1.25	.40	.02	.05
Beet, Long Red	93.25	1.13	.06	1.80	2.59	1.17	.32	.02	.05
CONCENTRATED FEEDS.									
Algeroba, or kiawe bean (*Prosopis juliflora*):[c]									
Sample No. 1	13.62	8.13	.67	52.38	21.87	3.33	1.35	.19	.29
Sample No. 2	16.37	8.50	.44	53.77	17.47	3.44	1.22	.23	.36
Sample No. 3	15.17	9.73	.45	47.12	23.71	3.82	1.38	.43	.33
Algeroba meal	9.29	10.25	1.16	47.98	27.85	3.52	1.22	.24	.39
MISCELLANEOUS FORAGE CROPS.									
Spanish needles (*Bidens pilosa*)[d]	82.06	3.45	.33	6.48	5.03	2.65	.94	.26	.14
Pakana (*Melilotus officinalis*)[e]	61.28	5.96	.67	17.59	11.90	2.60	.94	.50	.28
Rape[d]	86.10	2.24	.59	6.60	1.76	2.71	.95	.32	.16
Annual ilima (*Sida* sp.)[d]	77.58	3.93	.39	8.88	5.69	3.53	.81	.80	.32

[a] No. 1 and 2 from experiment station, Oahu; No. 3 grown at Waikiki, Oahu.

[b] From Kamehameha Schools, Oahu.

[c] Sample No. 1 was passed through a sieve having $\frac{3}{16}$-inch meshes, No. 2 through a sieve having $\frac{1}{8}$-inch meshes, and No. 3 was chopped coarse.

[d] From Molokai ranch.

[e] From Parker ranch.

Composition of Hawaiian feeding stuffs.

[Dry-matter basis.]

Kind of feeding stuff.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash constituents.		
					Potash.	Lime.	Phosphoric acid.
NONSACCHARINE AND SACCHARINE FORAGE.							
Sorghum:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Sample No. 1	6.89	7.08	54.45	21.90	1.23	0.48	0.35
Sample No. 2	6.53	1.60	55.39	26.52	1.30	.48	.43
Sample No. 3	6.81	2.00	59.18	22.95	....	.52	.67
Average	6.74	3.56	56.34	23.79	1.26	.49	.48
Sorghum silage	8.78	3.14	54.29	24.45	1.62	.36	.55
Corn cut for silo	6.97	1.01	53.78	27.31	1.40	.34	.05
Corn silage	11.19	1.70	35.96	23.69	2.59	.88	.49
Millet roots (*Sorghum halepense*)	8.13	.44	31.02	45.96	2.93	.07	.21

Composition of Hawaiian feeding stuffs—Continued.

[Dry-matter basis.]

Kind of feeding stuff.	Protein.	Fat.	Nitrogen free extract.	Crude fiber.	Ash constituents.		
					Potash.	Lime.	Phosphoric acid.
GRASSES.							
Hilo grass (*Paspalum conjugatum*):	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Sample No. 1	5.14	1.35	55.66	31.99	1.35	0.65	0.22
Sample No. 2	5.04	1.92	53.62	33.18	1.52	.53	.26
Sample No. 3	5.14	3.22	52.31	33.78	1.37	.69	.22
Average	5.10	2.16	53.86	32.98	1.41	.62	.23
Rhodes grass (*Chloris gayana*):							
Sample No. 1	8.01	1.47	45.65	35.62	1.41	.74	.45
Sample No. 2	10.04	1.72	42.78	30.69	1.47	.79	1.06
Average	9.02	1.59	44.21	33.15	1.44	.76	.75
Pili grass (*Heteropogon contortus*)	6.2	1.31	46.70	35.64	1.34	.24	.39
Para grass (*Panicum molle*):							
Sample No. 1	12.44	4.78	39.67	27.51	....	.56	.87
Sample No. 2	5.13	1.03	47.70	40.11	.29	.34	.42
Redtop (*Tricholæna rosea*)	3.71	1.32	49.53	38.92	.64	.36	.30
Paspalum dilatatum	7.25	2.67	55.97	32.77	1.92	.74	.44
Side oats grama (*Bouteloua curtipendula*)	10.63	1.73	45.72	29.94	1.18	.34	.44
English and Italian rye grass (*Lolium perenne* and *L. italicum*)	8.94	1.97	51 15	28.86	2.57	.61	.57
Wheat hay (containing some oats)	9.04	1.07	43.44	34.16	3.76	.23	1.16
Rice straw (upper half as gathered)	5.38	2.99	41.44	27.88	....	.44	.46
LEGUMINOUS FORAGE CROPS.							
Alfalfa:							
Sample No. 1	29.00	3.70	36.91	18.12	4.21	1.69	.88
Sample No. 2	20.06	2.91	42.81	21.26	3.83	1.33	.89
Sample No. 3	28.75	2.58	33.94	22.55	....	1.81	.80
Average	25.93	3.06	37.88	20.64	4.02	1.61	.85
Cowpea (*Vigna sandwichensis*)	17.31	3.29	41.03	23.93	3.52	1.94	.78
ROOTS USED AS FORAGE.							
Cassava refuse from crude extract of starch	1.44	.12	90.99	6.45	.37	.19	.05
Cassava waste (first washing for starch manufacture)	1.57	.26	95.37	1.29	.09	.12	.10
Taro waste	1.24	.83	93.41	3.03	.46	.16	.22
Tacca pinnatifida	5.82	.35	89.55	1.74	1.19	.18	.22
Ti root	7.06	.30	79.45	10.14	.50	1.05	.16
Beet, Yellow Tankard	17.06	.74	44.41	16.51	6.78	.28	.90
Beet, Long Red	16.87	.85	26.62	38.36	4.80	.24	.79
CONCENTRATED FEEDS.							
Algeroba, or kiawe bean (*Prosopis juliflora*):							
Sample No. 1	9.38	.77	60.69	25.31	1.56	.22	.33
Sample No. 2	10.14	.53	64.33	20.88	1.45	.28	.43
Sample No. 3	11.44	.53	55.56	27.95	1.62	.51	.39
Algeroba meal	11.26	1.27	52.90	30.70	1.34	.26	.43
MISCELLANEOUS FORAGE CROPS.							
Spanish needles (*Bidens pilosa*)	19.28	1.82	35.99	28.11	5.27	1.46	.81
Pakana (*Melilotus officinalis*)	15.39	1.74	45.43	30.73	2.44	1.30	.72
Rape	16.10	4.24	47.46	12.69	6.86	2.30	1.51
Annual ilima (*Sida* sp.)	17.55	1.76	39.55	25.37	3.62	3.60	1.46

Nitrogenous constituents of Hawaiian feeding stuffs.

[Fresh material.]

Kind of feeding stuff.	Total nitrogen.	Proteid nitrogen.	Amid. nitrogen.	Crude protein (total N × 6.25).	True protein (protein N × 6.25).	Amids calculated as asparagin.
NONSACCHARINE AND SACCHARINE FORAGE.						
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sorghum: Sample No. 1	0.274	0.244	0.030	1.71	1.53	0.14
Corn	.260	.181	.079	1.63	1.13	.37
GRASSES.						
Rhodes grass (*Chloris gayana*): Sample No. 1	.451	.278	.173	2.82	1.74	.81
Water grass (*Paspalum dilatatum*)	.314	.054	.260	1.96	.34	1.22
Pili grass (*Heteropogon contortus*)	.328	.245	.083	2.05	1.53	.29
LEGUMINOUS FORAGE CROPS.						
Cowpea (*Vigna sandwichensis*)	.489	.369	.120	3.06	2.31	.56
ROOTS USED AS FORAGE.						
Beet, Yellow Tankard	.161	.072	.089	1.01	.45	.42
Beet, Long Red	.182	.095	.087	1.14	.59	.41
CONCENTRATED FEEDS.						
Algeroba or kiawe bean (*Prosopis juliflora*):						
Sample No. 1	1.295	.781	.514	8.09	4.88	2.42
Sample No. 2	1.358	1.141	.217	8.49	7.13	1.02
MISCELLANEOUS FORAGE CROPS.						
Spanish needles (*Bidens pilosa*)	.552	.095	.457	3.45	5.94	2.15
Rape	.358	.289	.069	2.24	1.81	.32
Annual ilima (*Sida* sp.)	.629	.428	.201	3.93	2.68	.94

RICE INVESTIGATIONS—REPORT OF FIRST YEAR'S EXPERIMENTS.

By F. G. Krauss.

INTRODUCTION.

Rice, while second to sugar as an agricultural product and far below it in magnitude and value, is still the most extensively consumed in Hawaii of any product of the land. If every other crop should fail and supplies from the mainland be cut off, the subsistence of its inhabitants would be assured by this one staple crop.

The growing of rice occupies 10,000 or more acres, and as practiced in Hawaii it is an intensive rather than an extensive culture, 100 acres constituting a large plantation. The rentals of rice lands are high, ranging from $10 to $50 per acre per annum with water privileges. This necessitates careful and continuous culture to produce maximum crops, although the annual acre yields in Hawaii compare favorably with the best in the world. Two crops a year are usually grown on the same land, thus occupying the ground continuously, especially when slow-maturing varieties are grown. The usual practice is to propagate the seedlings in seed beds, from which the entire crop is transplanted by hand.

Tillage methods, while antiquated, are thorough, as is also the practice of irrigation and drainage. To a limited extent the application of fertilizers is followed. The sickle is used in reaping, thrashing for the most part is done by the treading of horses, and the grain is winnowed by hand.

The average annual yield (two crops) on good lands in favorable localities is 6,000 pounds of paddy per acre, while 8,000 pounds or more is not uncommon. At present prices,[a] which are exceptionally good, an acre will produce a crop valued at from $100 to $200. The estimated annual value of the Hawaiian rice crop in a favorable year is approximately $2,500,000.

In this report little more than a record of a first series of experiments is attempted. The data presented, however, were obtained under favorable conditions and should prove reliable on this account.

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[a] The price of paddy (unhulled rice) is about half of that of the milled marketable table rice, and during the spring of 1907 ranged from $2.20 to $2.70 per 100 pounds.

The writer desires to acknowledge the valuable assistance and cooperation of Messrs. Ching Shai, Wong Leong, and Ching K. Ai, prominent Hawaiian rice growers; Dr. N. A. Cobb, in the work on the diseases affecting Hawaiian rices and upon the sedges entering into these experiments; Mr. D. L. Van Dine, entomologist of the station, in determining insect pests affecting rice; and Miss Alice Thompson, assistant chemist, in preparing the chemical data affecting these experiments and in making numerous calculations. To Director Jared G. Smith's valuable suggestions and constant encouragement the main credit of much of this work is due.

PLANS, OBJECTS, AND METHODS OF THE EXPERIMENTS.

The past year has been devoted to a study of the fertilizer requirements of the rice plant and of rice soils, and to the development of superior varieties and strains of rice through the improvement of some of the best of the old varieties and by selection from the best foreign varieties. In connection with the experiments an exceptional opportunity was offered for determining a number of other factors in the production of rice. Among these are the influence of the age of seedlings at the time of transplanting; tillering of the rice plant as affected by the number of seedlings set in a clump at transplanting; relative yields from broadcasted, drilled, and transplanted rice; and the duty and influence of irrigation water.

In pursuing these investigations field trials were made of rice machinery. These took up comparatively little time, but sufficient was done to interest implement manufacturers, who will probably make more exhaustive tests than are possible by the station.

The station was fortunate in securing a conveniently located tract of land for experimental purposes. This land had been under rice culture for a number of years, excepting a small portion, which was planted to bananas at the time it was turned over to the station, in August, 1906. That portion which had been devoted to rice growing had received no fertilizer for a number of years, yet it had invariably yielded crops approximating 3,000 pounds of paddy per acre per harvest. However, owing to the porous nature of the soil, which necessitated an excess of irrigation, other crops were being gradually substituted for rice.

A chemical analysis of the soil was made at the time the station took possession of the land in 1906, and its principal constituents are shown in the following table:

Partial chemical analysis of the soil of the rice trial grounds.

	Per cent.
Moisture	8.435
Organic matter combined with water	9.253
Lime (CaO)	1.470
Magnesia (MgO)	1.575
Phosphoric acid (P_2O_5)	.436
Potash (K_2O)	.324
Nitrogen total	.232

This analysis shows the soil to be of fair fertility, although low in organic matter. Fully 25 per cent of this soil is coarse gravel and stone, an equal amount is fine gravel and coarse sand, and the remainder fine sand and silt with sufficient clay to permit of puddling the land to hold water enough for the crop.

An artesian well supplied ample pure water for irrigation purposes and avoided contamination in fertilizer experiments.

NOTES ON VARIETY TESTS AND IMPROVEMENT EXPERIMENTS.

In taking up the rice work the station secured as many varieties as possible, and early in 1906 succeeded in obtaining through the Office of Experiment Stations and the Bureau of Plant Industry of the U. S. Department of Agriculture about 150 more or less distinct varieties of rice. The descriptions and other data accompanying many of these varieties were meager but were carefully recorded, in order that the original descriptions could be compared with specimens grown from the different samples. A 10-gram sample of each variety was reserved for future reference, and these have already proved invaluable in the study of varieties in the two succeeding generations.

So far as the physical characteristics of the unhulled seed are concerned, comparisons that have thus far been made show but slight variation from the original specimens, except in color, the hulls invariably changing to a darker color with age, probably under the influence of light. It is possible that changes in environment may alter the chemical composition of the grain, and investigations in this direction are now under way.

Germination tests were made of all samples in the laboratory. One hundred and thirty-one varieties germinated, although some showed very weak vitality, due probably to the age of the seed, immaturity at harvest, or insect injury.[a] In several cases the bulk of the seed packet consisted of empty sterile glumes. The few seeds germinating from one of these lots produced perfect plants with a full crop of well-matured seed, while in another instance every flowering glume of the entire plant proved sterile. This would probably indicate a tendency toward sterility on the part of that particular variety, since the weather conditions were perfect at flowering time and the adjacent varieties fruited abundantly.

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[a] Several lots of seed, among them S. P. I. Inv. No. 12547, were found to be badly infested with the weevil (*Rhizopertha pusilla*).

Some stress is laid upon this point, as it frequently happens that in large fields numerous sterile or partially sterile plants are to be found which collectively would considerably reduce the yield. In the improvement of varieties any tendency toward a reduced yield is to be avoided. Whether the tendency to sterility can be transmitted remains to be determined.

In the improvement of varieties by selection as well as in testing varieties in cultural trials, it is of the utmost importance to know definitely their methods of pollination. In the case of the rice plant it has been generally supposed that cross-fertilization is the rule and self-fertilization the exception. Apparently the whole flowering process is favorable to cross-fertilization. The successive stages in the flowering are readily traced from the time in which the glumes open until they close together, enveloping the recently exposed stigma, and now containing the fertilized ovule which is to become the matured seed. The whole process of fertilization in rice is similar to that in wheat described by Hays,[a] except that the rice floret bears six anthers and opens generally between 9 and 10 o'clock in the morning and frequently does not close until noon. The flowering period of an individual floret is usually completed within an hour.

Based upon careful observation and experiment, the writer believes that self-fertilization is the rule in rice as it apparently is in wheat. Since these rice experiments were inaugurated more than 100 varieties have been grown in close proximity for from two to four generations without a single cross-bred plant having been found. To test the belief in self-fertilization numerous individual plants of several varieties were protected from foreign pollen by double fine gauze bags before the flowering stage, and all fertilized perfectly except those experimented with during periods of heavy rain.

In the original more than 100 varieties of rice received at the station from many sources there appeared considerable mixtures, which were at first believed to be due to deterioration or possibly to results of accidental crossing. To determine this point a variety grown experimentally at the Georgetown Botanical Gardens from imported Ceylon stock was selected as being the most impure of any. From this six or seven distinct types were separated and grown separately. All but one reproduced themselves closely as to type, so far as the physical appearance of the paddy was concerned. The second generation is now maturing, and, so far as harvested, each of the selections seems to maintain its original physical type.

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[a] U. S. Dept. Agr., Div. Veg. Physiol. and Pathol. Bul. 29.

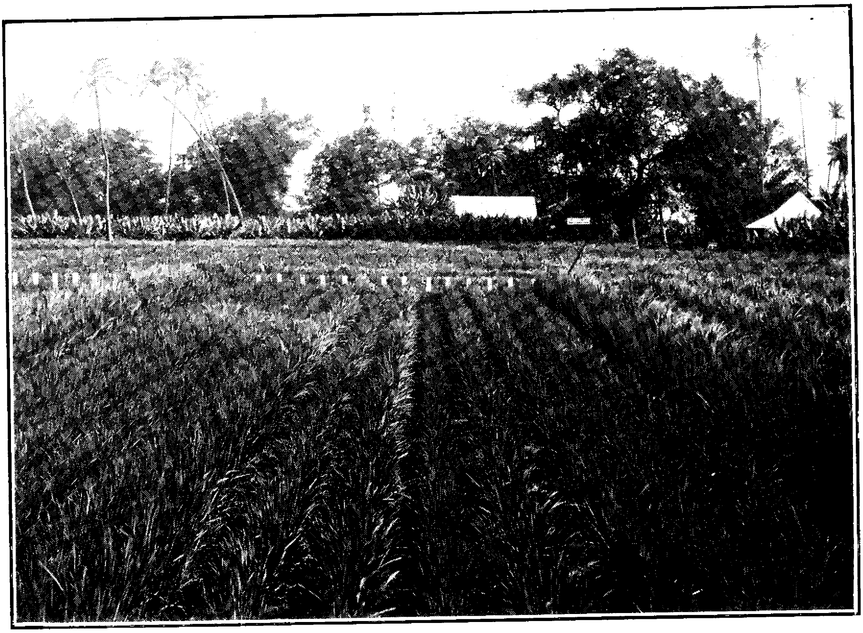

FIG. 1.—GENERAL VIEW OF RICE PLATS.

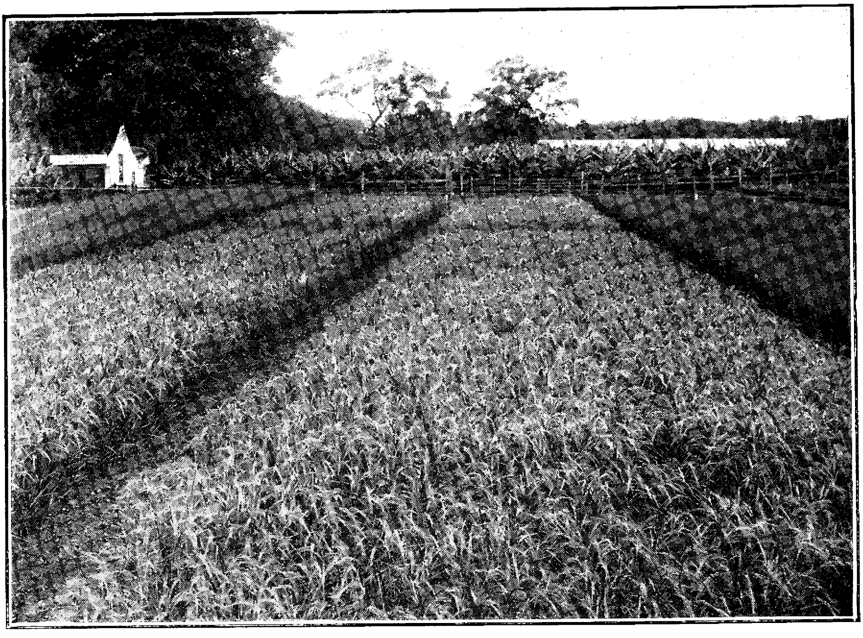

FIG. 2.—UPLAND RICE GROWN UNDER MINIMUM AMOUNT OF WATER.

A number of theories have been advanced to explain the cross-fertilization of cereals, but the author believes that the stigma does not become receptive until at the very moment the anthers shed their pollen. The pollen is then immediately received on the stigma and fecundation takes place. This seems to be borne out by the great rapidity with which the ovules develop. If this theory is true, the subsequent contact of foreign pollen is without influence. If, however, for some reason the stigma fails to receive pollen from the anthers in the same floret, then a deposit of foreign pollen may fertilize, even after a considerable interval of time. So far as the experiments have been carried on, however, there seems to have been no indication of crossing in the field.

METHODS OF CULTIVATION.

In the trial grounds near Honolulu an acre was divided into plats (Pl. V, fig. 1), and half of the tract was diked for permanent flooding and the remainder left for dry-land culture (Pl. V, fig. 2). It was planned to test each variety in both cultures to determine their drought-resisting and water-tolerance properties. After thoroughly tilling the land in a dry state with disk implements to a depth of 6 inches the first water was turned on August 20, previous to sowing the seed. In Hawaiian rice culture much of the tillage is done while the field is submerged. This is done partly to puddle the ground, thus economizing the irrigation water. The soil of these experimental plats being of a porous nature, as has already been mentioned, prevented any accumulation of surface water, and this necessitated the thorough puddling of the land, which was done with horses and a spike-tooth harrow. After this had been accomplished the 2-inch stream available supplied all the irrigation water needed.

After irrigating the tract the water was allowed to recede, and on account of the gravelly nature of the soil the drilling of the seed was commenced within forty-eight hours. To give all varieties an even start the entire list was sown August 25, flooded and immediately drained again, and so left until all the varieties had made several inches' growth.

Marked differences were noted in the germination of the varieties, the differences being due, it is believed, to the age of the seed, their moisture content, and the imperviousness of the hulls. The first varieties appeared above ground in fifty-eight hours and the last in one hundred and twenty-five hours, but no subsequent sowings from home-grown stocks have shown anything like as wide a range in germination. When the plants had attained a height of about 6 inches, they were thinned so as to stand about 6 inches apart. Equal numbers of the strongest, weakest, and intermediate plants were permitted to remain for the sake of obtaining as great diversity as possible. After the thinning was completed the land was permanently flooded.

Field notes were made throughout the season and comparisons made between the different varieties and several standard Hawaiian varieties under identical conditions. Records were kept of the amount of seed sown, tillering, date of flowering, date of maturity, germination, vigor, date of harvest, height and spread of plant, inclination to lodge, shattering of seed, freedom from disease, total yield and variation in yield of individual plants, quality, etc.

BREEDING EXPERIMENTS.

As each variety matured it was carefully inspected and all sports and rogues staked and recorded. The variety was then examined a second time and the best 20 plants pulled up by their roots. These were taken to the laboratory, and the fruit-bearing culms carefully compared until all but five plants were eliminated. The seeds of these were removed and weighed to determine the relative yields. Other things being equal, the two most prolific were reserved as seed for mother plants from which to develop a pedigreed stock. Wherever possible 100 plants of the unselected stock, including the 18 rejected plants from the first selection, were carefully thrashed, weighed, and the approximate acre yields calculated. In this calculation 100 plants were taken as representing a factor in estimating acre yields. In Hawaiian rice culture approximately 50,000 clumps, consisting of 4 or 6 plants each, are set per acre.

It should be stated that in Hawaiian culture all rice is transplanted, while in most of the experiments here described the seed was drilled directly into permanent rows, so that the yields as recorded from the comparative variety tests are only approximations of what they might be under the usual cultural methods.

Of the one hundred and more varieties under test, 11 have thus far been selected as being suitable for Hawaiian conditions. A number of these are upland rices, which produce a fair yield with a minimum supply of moisture. They are all hardy, having been brought from northern China, are early maturing, and produce an excellent hay for horses and cattle. Though all are of the bearded type, no ill effects have been observed to result from their feeding. There is every reason to believe that the culture of upland or dry-land rice will become an important factor in Hawaii's agriculture.

Among the varieties were some promising wet-land rices of the short, thick-kernel type characteristic of Japan rice, the demand for which is yearly growing, on account of the large population of Japanese in Hawaii. One of these varieties was introduced into Hawaii in 1903 or 1904 by Mr. Wong Leong, an extensive rice grower at Kailua, Oahu. Mr. Wong Leong imported four varieties of rice from Yokohama, Japan, only one of which proved suitable for Hawaiian conditions. Of this he now grows 50 to 80 acres annually and is constantly increasing the area. Comparatively little of this variety is grown elsewhere in Hawaii, but its culture is sure to extend as the demand for it increases.[a]

A pound sample of this variety was secured early in 1906 and sown in drills, the thinned-out plants being transplanted later. Much irregularity was noted as the plants matured. A small percentage showed a short-bearded form. Some tillered freely, while others produced only two or three fruiting culms. However, the seed set well, and its early maturity, compared with the slow-maturing Hawaiian varieties of the Gold Seed type, made a favorable impression from the first.

It was noticed in testing this variety that the transplanted seedlings tillered more freely and developed better panicles than the direct-sown seed; and, furthermore, that the earlier transplanted seedlings yielded almost twice as much seed as older seedlings transplanted later (see p. 88). This gives a valuable clue to a general complaint that the Japanese rices are small yielders when compared with the standard Hawaiian sorts. Careful selections were made of the best individual plants, and these form the basis of a choice pedigree strain which is about to be distributed by the station. This variety has been given a station inventory number, and it is frequently referred to in this report as No. 153.

A second variety, No. 144 (S. P. I. Inv. No. 12765), was received through the Office of Experiment Stations of the U. S. Department of Agriculture as coming from Japan and was labeled Ko-Zo.[b] The few seeds available were sown in August, 1906, but only a single plant was brought to maturity. The seed from this was preserved and carefully propagated. This variety tillers much more freely than No. 153, and the plants yield twice, and in some cases three times, as much paddy, although the grain is somewhat smaller in size. The quality of this rice is considered excellent, and the stock of it will be multiplied as rapidly as possible.

A variety known as No. 65 (S. P. I. Inv. 17144) is an Egyptian variety, extensively grown in Louisiana where, according to Dr. S. A. Knapp, it is locally known as "Bull Rice."[c] No variety in all the trials has made as good a showing from the very beginning and maintained its lead so well as this. Its general uniformity, good yielding qualities under wet and dry cultural methods, erect, vigorous growth, apparently small waste in milling, and its adaptability for all-season cropping commend it strongly as a general-purpose variety. Its culinary qualities are yet to be determined.

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[a] The Japanese residents in Hawaii prefer the rice imported from their own country, paying $1 more per 100 pounds for it.

[b] Possibly intended as Kiushu, a district in Japan where some of the best types of Japan rice are grown.

[c] Accompanying this variety were the following notes: "The Egyptian rice is locally known in Louisiana as 'Bull Rice' and has been grown there for many years. It has a berry of the Japanese type—that is, thick and short kernel, somewhat larger than the Kiushu rice, dark colored and much softer when it first ripens, so that it answers excellently for the purpose of stock feed.

A comparative study was made between plats of standard Hawaiian Gold Seed, Japan Seed rice, and the Egyptian variety just mentioned. These three varieties were grown under like conditions and represent results obtainable under the best methods of culture.

Comparison of standard Hawaiian Gold Seed, Japan Seed, and Egyptian varieties of rice.

Name of variety.	Station inventory number.	Date of sowing, 1907.	Date of maturity and harvest, 1907.	Growing period.	Height of plants.	Weight of paddy.[a]	Weight of straw.[a]	Estimated[b] acre yields, paddy.
				Days.	*Inches.*	*Grams.*	*Grams.*	*Pounds.*
Standard Hawaiian Gold Seed	148	Feb. 18	July 20	152	42	32	68	3,730
Hawaiian-grown Japan Seed	153	do	June 8	110	36	20	54	3,412
Hawaiian-grown Egyptian	65	do	July 20	152	48	43	114	4,129

[a] One clump consisted of three plants set 12 by 12 inches apart, except No. 153, which stood 9 by 9 inches apart.

[b] Based on 43,560 clumps to an acre for varieties Nos. 148 and 65, and 77,440 clumps to an acre for No. 153.

The comparison in this case is believed to be a fair approximation of these varieties. The estimates are based on test cuttings of 100 square feet, the range of error for which has been found to be within 150 pounds of the yield per acre.

Variety No. 152, which was received by the station from Mr. W. S. Lyon, horticulturist in the Bureau of Agriculture, Philippine Islands, under the name Ay-Yujip, from the Igorrote country, where it is classed as the very best rice grown, promises to become a valuable variety, especially for windy locations. In an extensive trial conducted with it during the fall and winter of 1906–7 the severe storms failed to lodge a single plant, and the grain set perfectly, yielding a large crop. The panicles are long and drooping, averaging 10 to 12 inches in length, and are well furnished with seed, though not so compactly as in variety No. 65. The grain is of a characteristic Japanese type, but owing to the short bearded or awned form of the paddy, it would probably not mill so economically as the beard-

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It also has more protein than the ordinary rice. The characteristics of its growth are that it requires very little water, has a strong stalk, abundant leaf, is a heavy producer, and will generally make a crop even though the other rices fail. For these reasons it is grown as a stock feed. The seed of the particular rice sent in was obtained about five years ago [through a seed dealer of New Orleans]. It was the only seed which I could purchase which was free from red rice."—KNAPP.

less varieties. A considerable variation prevails in the extent of this awned form, and it is hoped that by selection it will be possible to establish an entirely beardless type. Considerable improvement is already noted in this direction.

Variety No. 42 (S. P. I. Inv. 12867) proved another promising variety, bearing very compact panicles of upright growth, which permits of close planting as an offset to its rather light tillering. This variety was sent to the station under the name Thosar Bhadai ghaiya, from Bengal Province, India.

In the search for a better variety than the Hawaiian Gold Seed, which is the variety grown most extensively in Hawaii, variety No. 39 (S. P. I. Inv. 12852) proved superior in many respects to our best Hawaiian varieties, which it closely resembles in general appearance. The selection made by the station has unusually compact panicles, the spikelets being attached to the peduncles at close intervals, set on short pedicels, which cause the spikelets to lie close together, often overlapping for two-thirds their length. In the Hawaiian strains of Gold Seed the panicles are rather loose and straggling, due to the longer internodes, so that a comparison between the panicles of the two strains shows 10 to 20 per cent more seed in favor of the new variety, due to this cause alone, since the panicles are of about equal size.

This close setting of the seed to produce compact panicles is an important character to be considered in developing the yielding power of rice through selection. It was so noticeable in the early experiments that its application has been practiced almost from the beginning. Attention has been called to this character by Dr. T. Nakamura, of Tokyo, and it has also been pointed out by Mr. Wong Leong, who called attention to its importance.

SUMMARY.

In the improvement of varieties of rice, it is found important to collect and compare as many varieties as possible. Superior varieties may already exist, and by their cultivation time and expense of creating new sorts would be saved. In work of this character selection should never cease, even among the best varieties.

In testing varieties by cultural trials, a single season's test is not sufficient for comparison. In rice, especially where two crops are grown annually, it is of importance to grow all varieties, testing them as spring and fall crops. The experiments have demonstrated that some varieties which yield well from July planting fail if sown in the early spring, or continue to vegetate until late fall, when they flower and fruit at about the same time as summer plantings. As an example of this No. 19 (S. P. I. Inv. 12508), sown August 25, 1906, yielded a splendid crop when harvested December 17, 1906.

On March 7, 1907, a large plat was sown to the same variety, and while the plants had reached the height of 5 to 6 feet on October 20 only an occasional plant was coming into flower. This indicates periods for maturity of 118 days for fall planting and 200 days for spring-planted crops.

All things considered, the all-season varieties are best for Hawaiian conditions, although exceptional qualities in fall varieties may sometimes be used to advantage in a cultural scheme. It may be laid down as a principle that spring varieties also produce fall crops, while fall varieties are not at all suited to spring culture. Fall varieties are usually slow maturing and heavy yielders; they tiller well, and have thick, stiff stems, being resistant to the effect of storms.

The commercial value of the several varieties which the station is about to introduce to the rice growers of Hawaii remains to be proved, and this can be done only in their hands under the varying and less ideal conditions of plantation management.

FERTILIZER AND CULTURE EXPERIMENTS.

INTRODUCTION.

The Hawaiian rice lands have long been noted for their fertility. Under the intensive cultural methods practiced by the Chinese they have yielded crops of extraordinary quantity and fine quality, and in consequence the industry has flourished. However, decreasing yields and deterioration in the quality of the grain are beginning to cause a general awakening. The causes of the smaller and poorer yields are the continuous cropping of lands with this one staple and the lack of a rational system of fertilization to compensate for the heavy drain imposed by the harvesting of two crops annually.

Ordinarily a rotation of crops would suggest itself as a feasible remedy, but the fact that rice is grown on submerged lands restricts its culture to very narrow limits. As a means for the restoration of worn-out rice lands resting the land has been advocated, but the high rentals prevailing practically prohibit the application of this remedy. Some advance has been made in this direction in that paddy fields are being more thoroughly drained at harvest, and the field is permitted to remain in stubble for as long a period as practicable. The fields are then plowed in a half-dry state and left exposed to the air and sun. After varying periods the land is flooded and the resulting mud mass very thoroughly mixed with the Chinese harrow (Pl. VI, fig. 1). This implement is a single-rowed, twelve-toothed contrivance of steel, resembling an immense comb, to which a water buffalo is attached where the land is very soft or a horse where there is good bottom.

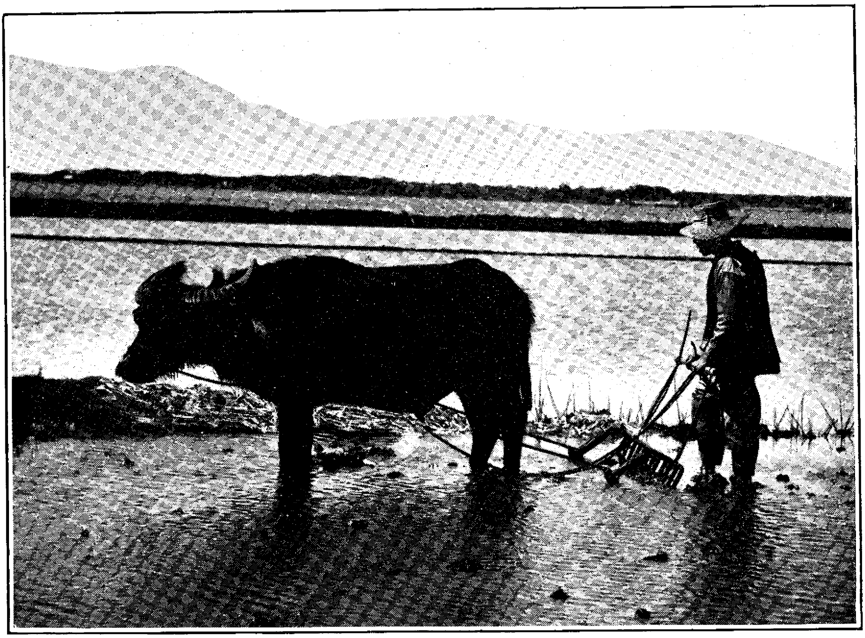

FIG. 1.—CHINESE HARROW.

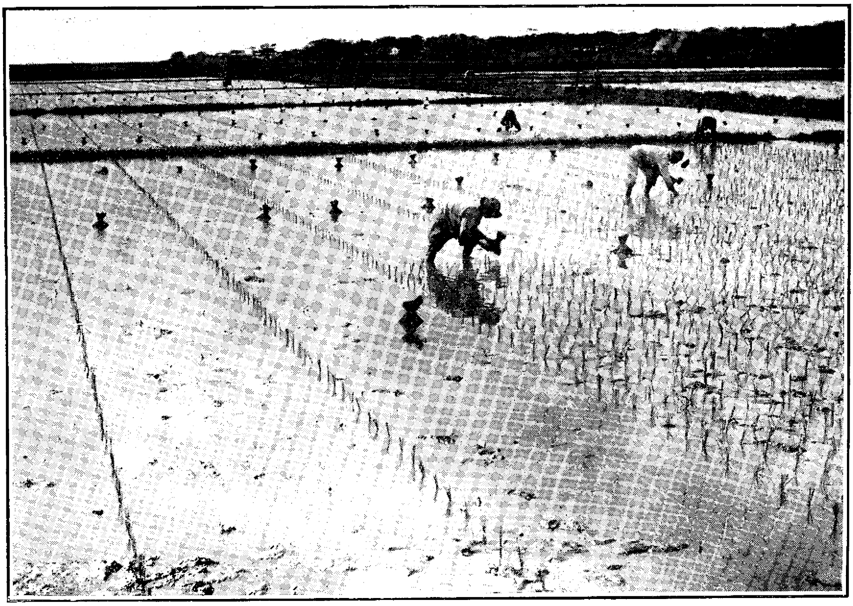

FIG. 2.—TRANSPLANTING RICE SEEDLINGS.

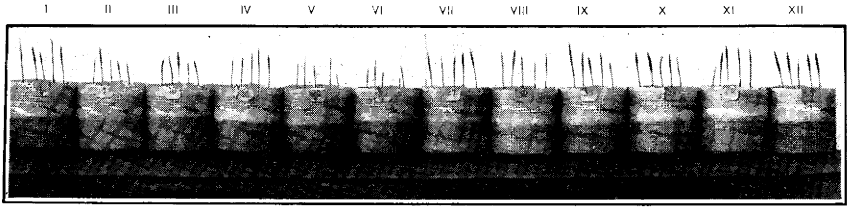

FIG. 1.—STAGE WHEN FIRST WEIGHED, AUGUST 15, 1906.

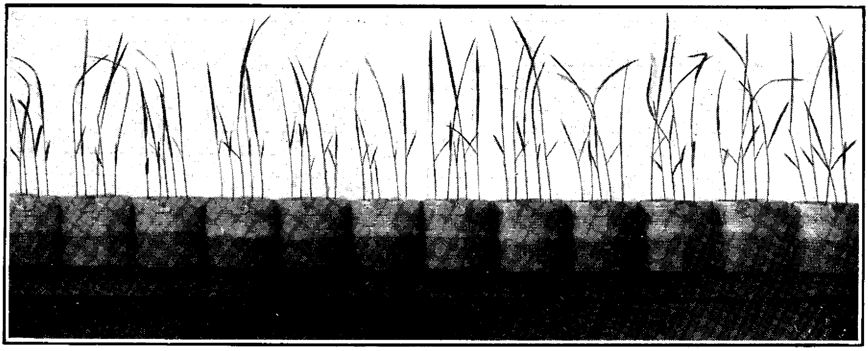

FIG. 2.—INTERMEDIATE STAGE, AUGUST 24, 1906.

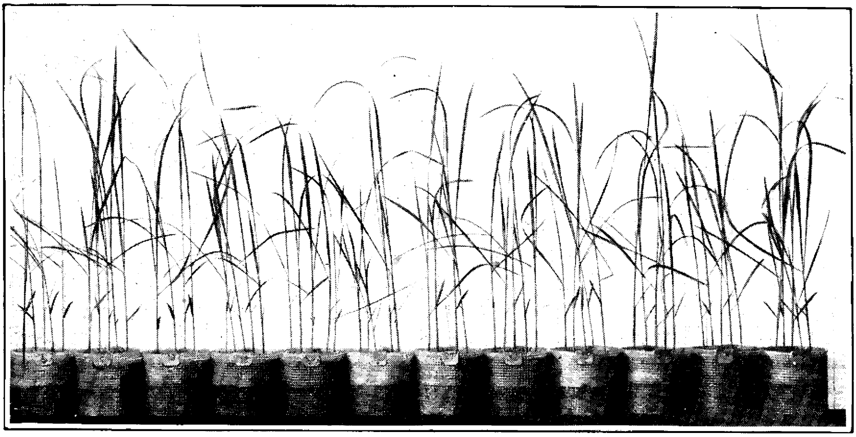

FIG. 3.—CONDITION AT FINAL WEIGHING, SEPTEMBER 24, 1906.

POT EXPERIMENTS WITH RICE, SHOWING EFFECT OF FERTILIZERS.

After this preparation the soil is in condition to receive the crop, and it should be borne in mind that all rice in Hawaiian culture is transplanted (Pl. VI, fig. 2). While such tillage prepares a suitable seed bed, the more important object of cultivation while the field is flooded is to puddle the soil so as to make it more retentive of water. The value of this treatment will be better appreciated when it is known that puddled soils retain their surface flooding from ten to fifty times better than unpuddled fields.

FERTILIZER EXPERIMENTS.

The possibility of economically increasing the yield of the rice crop by the application of commercial fertilizers has doubtless been apparent to many. One would think that in Hawaii, with its splendid object lesson of the results of fertilization of the cane crop, the analogy would readily have suggested itself with other crops. Beyond the application of natural manures, such as have been used for centuries in oriental countries, comparatively little seems to be known of modern methods in plant feeding in relation to the rice crop.

With a view to discovering if possible some of the fertilizer requirements of rice, a series of experiments was planned to determine the influence of chemical fertilizers and natural manures upon the growth and composition of the rice plant under Hawaiian conditions. Two series of soil tests were made by laboratory pot-culture methods, a duplicate series of field plat experiments, and two series of experiments on a field scale. The period covered by these experiments was about fifteen months, beginning July 1, 1906.

The first experiment undertaken was the determination of the manurial requirements of the soil of the rice trial grounds (Pl. VII). For this purpose the paraffined wire-pot method devised by the Bureau of Soils of the U. S. Department of Agriculture was used.[a] This method possesses several advantages over the more cumbersome pots ordinarily used in such cultures, foremost among the advantages being the facility with which transpiration as a determination of growth may be measured, the more normal development of the root system, and the economy of space.

A disadvantage was found in a submerged culture, such as rice, in the danger of leakage liable from the puncture of the frail paraffin covering of the pots. The experiment, however, proved the adaptability of the method, and it was found that the measure of growth as determined by the amount of water transpired by the plants approximated closely the relative weights of the plant in the green and moisture-free conditions.

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[a] U. S. Dept. Agr., Bur. Soils Circs. 15, 18; Rhode Island Sta. Buls. 109, 120; Ohio Sta. Bul. 168.

The pots being very small, only 3 inches in diameter and 3 inches deep, the plants could not be grown to maturity, so a period of about thirty days' growth was fixed as the limit, and five rice seedlings were placed in a pot. It has been pointed out,[a] and is also the common observation, that decided soil deficiencies are indicated by the crop long before it has reached its maturity. In so far as a crude but rapid determination of the immediate manurial requirements of the soil is useful as a guidance for further experiment, the wire-pot method commends itself to workers along these lines.

EXPERIMENT I.

This experiment was carried out on lines set forth in Circular 18 of the Bureau of Soils, except that the optimum moisture condition of the soil was made complete saturation, or slightly in excess. This was necessary to supply as normal a condition as possible for rice culture. The soil of the trial grounds was selected for this and most of the subsequent experiments, not because it was typical of the large area of rice lands in the islands, but because it lent itself to a great range of artificial modifications.

A composite sample of the soil was taken, thoroughly mixed and pulverized, after which various fertilizers were added, the amounts used approximating those employed in ordinary field practice. The fertilizers added were dry manure at the rate of 5 tons per acre; lime, 1 ton; nitrate of soda, 200 pounds; sulphate of potash, 200 pounds; acid phosphate, 200 pounds; nitrate of soda and sulphate of potash, 200 pounds each; nitrate of soda and acid phosphate, 200 pounds each; sulphate of potash and acid phosphate, 200 pounds each; nitrate of soda, sulphate of potash, and acid phosphate, 200 pounds each; nitrate of soda, sulphate of potash, and acid phosphate, 200 pounds each, to which was added lime, 2,000 pounds; and nitrate of soda, 200 pounds, applied in ten doses at three days' interval. After mixing the fertilizer with the soil it was allowed to stand for several days, when the baskets were filled and the pots arranged in twelve series, each series containing four pots.

Carefully selected one-week-old seedlings of the Hawaiian Gold Seed were used in this experiment, and after they had attained a height of about 1 inch, five seedlings were transplanted to each pot and permitted to attain a growth of 2 inches. The optimum moisture condition having been provided, the pots were sealed over, weighed, and photographed on August 15. From this date they were weighed at three-day intervals until the termination of the experiment, which in most cases was thirty days.

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[a] Rhode Island Sta. Bul. 109.

A summary of the results obtained is given in the accompanying table:

Summary of pot experiments with rice, showing effect of fertilizers on growth.

Series No.	Fertilizer used and calculated rate per acre.	Water transpired by 5 plants in total period of growth.	Green weight of 5 plants at end of 30-day period.	Water-free weight of 5 plants at end of 30-day period.	Water transpired per pound of water-free substance.
		Grams.	*Grams.*	*Gram.*	*Pounds.*
1	Check (no fertilizer)	202.0	1.92	0.42	480.95
2	Stable manure 5 tons	287.4	2.75	.60	479.00
3	Lime, air-slaked 1 ton	296.3	2.75	.57	519.82
4	Nitrate of soda 200 lbs	276.1	2.57	.57	484.38
5	Sulphate of potash 200 lbs	298.1	2.75	.57	522.98
6	Acid phosphate 200 lbs	276.7	2.57	.57	485.44
7	Nitrate of soda and sulphate of potash 200 lbs. each	299.7	2.47	.60	499.50
8	Nitrate of soda and acid phosphate, 200 lbs. each	292.9	2.67	.57	513.86
9	Sulphate of potash and acid phosphate 200 lbs. each	235.1	2.37	.50	450.50
10	Nitrate of soda, sulphate of potash, and acid phosphate 200 lbs. each	314.6	2.67	.60	524.33
11	Nitrate of soda, sulphate of potash, and acid phosphate, 200 lbs. each, and lime, 2,000 lbs	273.3	2.50	.55	496.91
12	Nitrate of soda, applied in 10 doses, 3 days apart 200 lbs	420.2	4.40	.95	442.10

In the above table the first column gives the amount of water transpired, the second the green weight of the five plants at the end of the experiment, the third the dry weight of the plants, and the fourth the amount of water transpired for each pound of water-free substance produced. This last column, which is the result of computing the other data, shows that the rice plant during the first thirty days of its growth transpires approximately 500 pounds of water to every pound of dry material produced. The smallest proportionate transpiration occurred in the series receiving nitrate of soda at intervals during the experiment, and this series also produced the greatest growth. The next lowest transpiration was found in the series receiving sulphate of potash and acid phosphate.

The most striking result obtained in this experiment was the superior growth obtained where the nitrate of soda was supplied in ten equal doses. The results obtained in this series if compared with the series in which the same amount of nitrate of soda was applied all at one time show marked contrast. The second important result of this experiment is shown in the series where a ton of lime was added to the complete fertilizer. This apparently depreciated the yield below the unlimed series fully 10 per cent. These results are not confirmed in the series which received lime only, but subsequent field experiments strongly emphasized the fact that lime had a depressing effect upon the crop, in the yield of both grain and straw.

The other treatments appeared to exercise a beneficial influence upon the growth of the seedlings, but the results are such as not to permit of definite conclusions. The least beneficial results were obtained where a combination of potash and acid phosphate was used. In subsequent experiments these two substances gave maximum yields from much smaller applications.

EXPERIMENT II.

The object of this experiment was to determine, so far as possible, by means of pot cultures, the influence upon the yield of grain and straw of the various elements found in commercial fertilizers, used in combination with and without lime. It was planned to grow the plants to maturity, hence larger pots were necessary than those afforded by the paraffined wire-pot method, and glass jars holding 2½ kilograms of dry soil were substituted. Three jars constituted a series. One received an application of lime in addition to the regular fertilizer, the other two remained unlimed. One of these was devoted to a lysimeter experiment, the results of which were too inconclusive for publication. A duplicate of this experiment is under way.

To each pot six selected seedlings of Japan variety No. 153 were transplanted. The soil used was that from the trial grounds, the same as in Experiment I, except that a crop of rice had been harvested since the first experiment. All the fertilizers were mixed with the soil before planting and were contained within the first 3 inches of the soil. The fertilizers were applied at the rate of 50 pounds per acre for each element.

The results of this experiment were not recorded in actual weights, but marked differences were noted in the appearance of the plants at the end of the experiment. One of the striking results obtained was the general depression of the plants when treated with lime, the loss amounting to from 14 to 40 per cent. Subsequent field trials confirm these results. S. Suzuki[a] suggests that the injurious effect of lime may be due to the neutralization of the acids exuded by the roots, in consequence of which less food becomes available to the plants. The depressing effect of liming rice soils is recognized in Japan. Dr. T. Nakamura informed the writer that the liming of rice soils in the Kiushu district of Japan is prohibited by law.

The general results of this experiment indicate that nitrogen in the form of sulphate of ammonia is especially suitable for the rice plant, and this fact was further borne out in plat experiments and also when tried on a field scale in a different locality. Where the nitrogen was supplied in the form of fish guano, the results agreed closely with those obtained where sulphate of ammonia was used. Next to the beneficial results obtained from nitrogen in the form of sulphate of ammonia and fish guano, acid phosphate seems to be the most avail-

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[a] Bul. Col. Agr., Tokyo Imp. Univ., 6 (1905), No. 4, pp. 347-351.

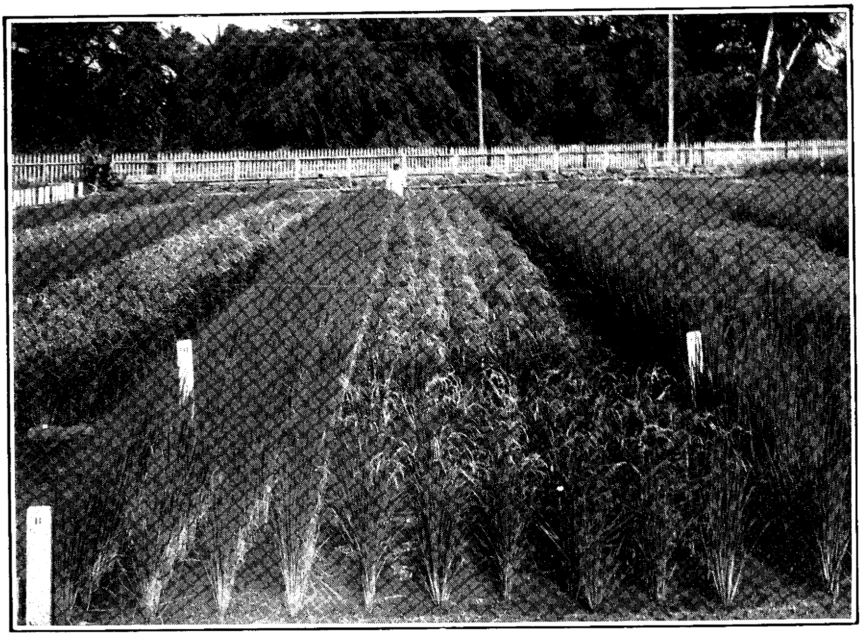


FIG. 1.—COMPARISONS OF GOLD SEED AND JAPAN RICE. JAPAN SEED ON RIGHT, GOLD SEED ON LEFT.

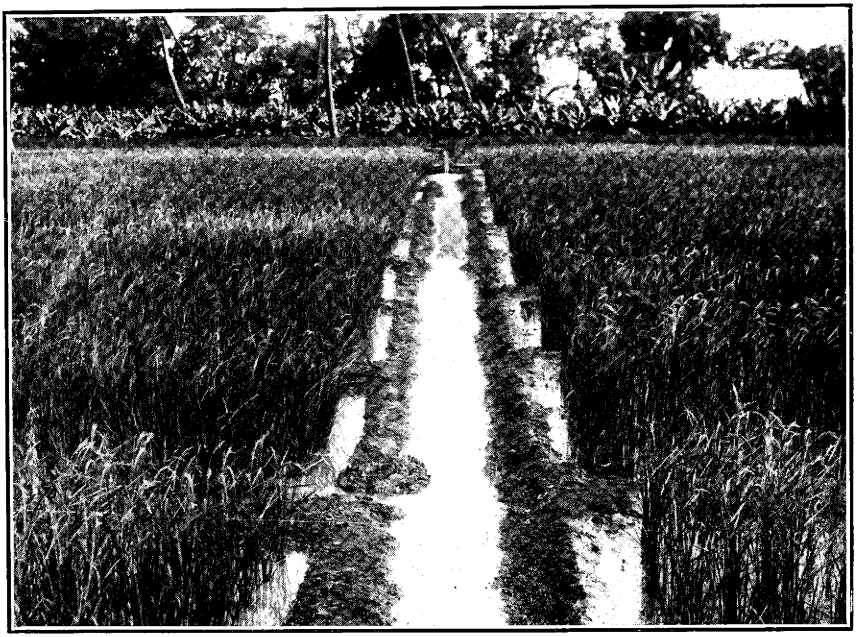


FIG. 2.—SHOWING METHOD OF IRRIGATING FERTILIZER PLATS.

able for the rice plant. The best combination of the two elements was distinctly in favor of nitrogen and phosphorus in the form of sulphate of ammonia and acid phosphate and fish guano and acid phosphate, the two combinations being of about equal value. Next to these combinations fish guano and sulphate of potash, sulphate of ammonia and Thomas slag, fish guano and Thomas slag, sulphate of ammonia and sulphate of potash, and fish guano and muriate of potash gave results in about the order named. Where a complete fertilizer made up of the several forms of these different fertilizers was used, practically all the plants were killed within a month.

EXPERIMENT III.

The object of this experiment was to determine the relative value of different fertilizers when applied to two widely different types of rice—the Hawaiian Gold Seed, a heavy-strawed, slow-maturing, starchy rice, the standard used by the Chinese, and the dwarf, early maturing, glutenous Japan rice, largely used by the Japanese (Pl. VIII, fig. 1). The field selected for this experiment had been devoted to rice culture for a number of years without any fertilization and it had uniformly produced a fair crop, the stand being characterized by an exceptional evenness of growth. A further advantage of this locality was an ample supply of pure artesian water and a fairly well sheltered location (Pl. VIII, fig. 2).

The fertilizers were supplied in as varied selection as the market afforded and such as can always be obtained in Honolulu. Where single constituents were added the amounts supplied in the fertilizer tests were 40 pounds of nitrogen, 25 pounds of phosphoric acid, and 45 pounds of potash, these quantities being based upon the plant food ingredients removed by a good crop of rice.

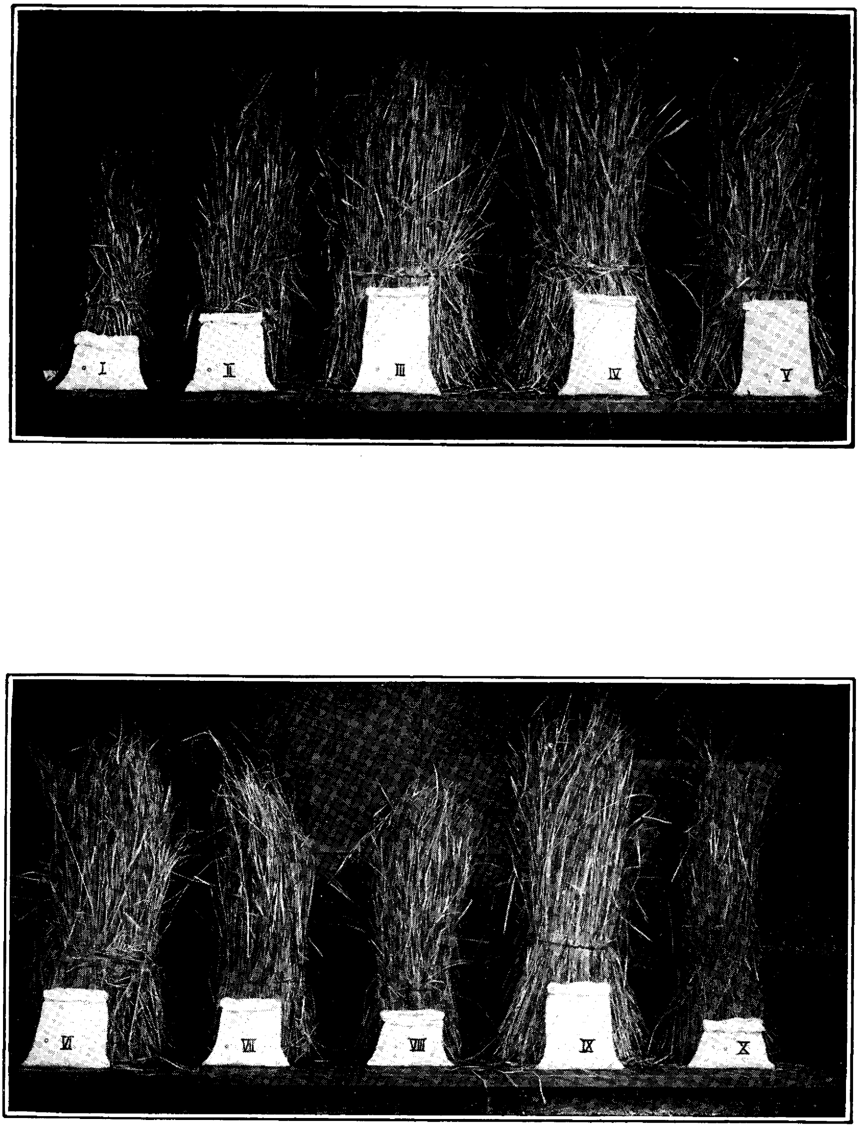
Each plat was divided into four sections. One was untreated, the second fertilized before planting, the third fertilized before planting and in addition limed at the rate of 750 pounds of air-slaked lime per acre, and the fourth was fertilized after the plants were three-fourths grown. Where the fertilizers were applied before planting they were worked into the dry soil and the soil left for one week, when the seed was drilled to a depth of 1 inch in rows 12 inches apart. Immediately after planting the plats were lightly flooded and the water at once permitted to recede.

Each plat was sown with two varieties of rice, the Hawaiian Gold Seed (No. 148) and the Japan Seed (No. 153). When the seedlings were 3 inches high they were thinned so as to stand 3 inches in the row, and the plats again flooded and the water allowed to cover the surface of the soil until nearly harvest.

The influence of lime in connection with and without the addition of fertilizers was determined. The uniformly negative results obtained from liming, while they can not be taken as a criterion for all rice soils, seem to show the error in indiscriminately recommending liming for all rice lands. Hawaiian rice lands are submerged for the greater part of the year, but only one out of six typical rice areas showed an acid reaction, and it is probable that this soil would have been benefited by liming.

The effect of the different treatments on the yield of Japan rice is shown in the accompanying table (see also Pl. IX).

PLATE IX.



EFFECT OF DIFFERENT FERTILIZERS ON YIELD OF JAPAN SEED PADDY AND STRAW.

[Numbers on bags correspond with plat numbers in table.]

Relative value of the various commercial forms of nitrogen, phosphoric acid, and potash as fertilizers for the rice crop.

Plat number.	Fertilizer applied.	Amount per acre.	Equivalent.	Check (untreated).				Fertilized before planting.				Limed (750 lbs.) and fertilized before planting.				Fertilized after plants were three-fourths grown.			
				Paddy.	Sterile glumes.	Straw.	Average of 10 plats.	Paddy.	Sterile glumes.	Straw.	Paddy, gain (+) or loss (−).	Paddy.	Sterile glumes.	Straw.	Paddy, gain (+) or loss (−).	Paddy.	Sterile glumes.	Straw.	Paddy, gain (+) or loss (−).
		Lbs.	*Lbs.*	*Lbs.*	*Gms.*	*Lbs.*	*Lbs.*	*Lbs.*	*Gms.*	*Lbs.*	*Per ct.*	*Lbs.*	*Gms.*	*Lbs.*	*Per ct.*	*Lbs.*	*Gms.*	*Lbs.*	*Per ct.*
1	Nitrate of soda	266	40 N	3.51	56	4.55	Paddy 3.78 Straw 5.29	4.76	28	5.21	+ 25.92	3.18	85	4.20	−15.87	5.06	157	8.03	+33.33
2	Sulphate of ammonia	200	40 N	3.66	61	4.80		7.12	63	9.15	+ 88.36	3.37	105	4.68	−10.84	5.34	168	8.41	+41.27
3	Sulphate of potash	95	45 K_2O	3.93	59	5.20		10.15	84	13.09	+168.52	2.87	294	6.56	−24.07	2.90	84	5.08	−23.27
4	Sulphate of potash and magnesia	180	45 K_2O 61 $MgSO_4$	3.81	44	5.55		9.06	112	12.81	+139.68	3.75	168	6.01	− 0.79	3.47	28	4.87	− 8.20
5	Acid phosphate	125	25 P_2O_5	4.02	70	6.10		8.75	119	13.15	+131.48	2.15	217	5.44	−43.12	4.59	94	6.98	+21.42
6	Reverted phosphate	156	25 P_2O_5	3.90	73	5.25		6.31	172	14.78	+ 66.93	2.06	112	3.81	−45.50	3.12	52	5.62	−17.46
7	Thomas slag phosphate	156	25 P_2O_5 62 CaO	4.26	60	5.76		5.56	42	7.50	+ 47.07	2.75	147	5.43	−27.25	3.12	28	5.01	−17.46
8	Complete fertilizer (nitrate of soda, acid phosphate, and sulphate of potash)	350	28 N 17.5 P_2O_5 31.5 K_2O	3.75	62	5.20		4.75	35	5.56	+ 25.66	3.12	140	4.48	−17.46	3.70	42	5.46	− 2.11
9	Complete fertilizer (sulphate of ammonia, fish guano, reverted phosphate, and sulphate of potash)	350	28 N 17.5 P_2O_5 31.5 K_2O	3.66	56	5.80		7.55	91	13.10	+ 99.73	3.37	103	3.93	−10.84	3.57	88	6.26	− 5.55
10	Complete fertilizer (nitrate of soda, Thomas slag phosphate, and sulphate of potash and magnesia)	350	28 N 17.5 P_2O_5 31.5 K_2O	3.30	51	4.50		3.94	49	5.31	+ 4.23	3.00	63	3.75	−20.63	4.31	49	5.27	+14.02

In reviewing the figures it appears that the average production of the ten untreated plats was 3.78 pounds of paddy and 5.29 pounds of straw. The greatest gain in paddy from any one fertilizer when applied before the crop was planted was from sulphate of potash, which yielded a gain of 168 per cent over the untreated plats, an equivalent of 2,522 pounds of paddy per acre. This additional yield, valued at $2.50 per 100 pounds, represents an increased value of $63, produced at a cost of less than $5 for fertilizer. The next largest increase in yield was on plat 4, to which the double phosphate salts were added; the acid phosphate came next, the complete fertilizer composed of sulphate of ammonia, fish guano, reverted phosphate, and sulphate of potash next, followed by sulphate of ammonia, reverted phosphate, Thomas slag, nitrate of soda, etc. While all the fertilizers produced some gain, the experiment shows the importance of the particular form in which the different constituents are supplied.

Where the fertilizers were applied after the plants were three-fourths grown, as is the general Hawaiian practice, radically different results were obtained. As might have been expected, the nitrate of soda was more effective than where applied before planting, especially in the increase of straw. On the other hand, the slowly acting sulphate of ammonia showed a decrease in yield when the fertilizer was supplied during the growing period. All forms of potash appeared to have exerted a detrimental effect and the different forms of phosphate showed a considerable decrease as compared with the same fertilizers when added before planting. As in the other experiments, the addition of lime depressed the yield of grain in all cases and in many instances the amount of straw also.

In a second experiment, in which the Hawaiian Gold Seed variety of rice was used, results almost identical with those given in the above table were obtained. The greatest benefit was secured from the use of sulphate of potash when fertilizers were applied before planting, the benefits of the remaining treatments being about in the same order as described for the treatment with Japan rice. Two notable exceptions, however, were observed. The reverted phosphate gave only 66 per cent gain over the untreated plat with the Japan Seed, while the gain for the Gold Seed amounted to 132 per cent. In a similar way the complete fertilizer used on plat 10, which gave only 4 per cent increase with the Japan Seed, showed an increase of 86 per cent for the Gold Seed. These increases may possibly be explained by the fact that the season of growth of the Gold Seed is fully forty days longer than that of the Japan Seed, and it is reasonable to believe that this additional growing period rendered available a proportionate additional amount of the slowly soluble constituents in these forms of fertilizers.

In comparing the limed section in this experiment with the experiment with the Japan rice it was noticed that a less depressing effect was exerted on the slower growing variety, although a considerable decrease as compared with the corresponding plats not limed was apparent.

Where the plants were fertilized when they were two-thirds grown practically the same beneficial effects for nitrate of soda and sulphate of ammonia were noted for both varieties of rice. The sulphate of potash, which slightly decreased the yield of Japan Seed when applied after the crop was well advanced, appeared to exert a slight benefit on the later maturing Gold Seed variety. Slightly beneficial effects were also obtained from the acid phosphates, reverted phosphates, and complete fertilizers.

EXPERIMENT IV.

Less than a decade ago practically the only fertilizers used in Hawaiian rice culture were fish refuse (fish guano and shrimp skins), Chinese peanut cake, and stable manure, the first two being imported either from China or from California in large quantities. At present stable manure is about the only material used, the high price of importations from China and the scarcity of materials elsewhere prohibiting their general use. The beneficial effect resulting from this class of manures is often commented upon by Chinese rice growers, and it was on this account that an experiment was planned to compare the value of these old-time fertilizers with the modern commercial manures.

Accordingly plat experiments were carried out with Japan Seed rice, using the materials available at Honolulu at the time. These were Chinese peanut cake, fish guano, and stable manure. The shrimp skins, once so largely used, were unobtainable, and a much-advertised and largely used commercial fertilizer was substituted. Owing to its concentration and extreme solubility it was thought that such material might possess useful features if produced cheaply enough.

A partial analysis of the fertilizing materials was made by the station chemist, and showed that the horse manure contained 0.41 per cent of nitrogen, 0.507 per cent of phosphoric acid, and 0.471 per cent of potash, and the fish guano 8.58 per cent of nitrogen and 6.95 per cent of phosphoric acid. The analysis of the commercial fertilizer was furnished by the manufacturer, and it is claimed that the substance contains 15 per cent of nitrogen, 5 to 6 per cent of water-soluble phosphoric acid, and 3 to 4 per cent of potash.

As in the previously described experiments, each plat received different treatments, some being fertilized before planting and others when the plants were two-fifths grown. On some plats lime was used, while on others it was omitted.

As in practically all the other experiments, the addition of lime seemed to exert a depression in the yield of the crop, except on the plat receiving stable manure at the rate of 5 tons per acre.

In comparing the relative value of the application of fertilizers before sowing the crop with the results obtained where the fertilizers were applied after the crop had become well advanced, there appeared to be little difference so far as the experiments with Chinese peanut cake were concerned, but since the results in either case were poor, no weight is attached to this part of the experiment. On the other hand, the fish guano showed a decided gain in the application made before the crop was sown. This was also true of the commercial fertilizer.

In comparing the relative value of the several fertilizing materials, stable manure showed an increase of 121 per cent of paddy for an application of 2½ tons per acre, while an application of 5 tons per acre yielded 250 per cent increase over the check and over 100 per cent more than the section receiving half as much manure. The application of stable manure also greatly increased the yield of straw in proportion to the amount of grain. Next in value to the stable manure was the fish guano, which gave an increased yield of 118 per cent over the check plat, followed by the commercial fertilizer with an average gain of 100 per cent when it was applied at the rate of 100 pounds per acre. It was thought that the extreme solubility of the materials composing the commercial fertilizer would especially adapt it as a food stimulant in later applications, but this does not appear to hold true so far as this experiment is concerned. The late application of fish guano resulted in a considerable decrease in the yield as compared with the early application.

Comparing the results of the same treatment upon the Gold Seed variety a close agreement was found throughout the experiment.

EXPERIMENT V.

This and the two following experiments were carried on in cooperation with the Punaluu rice plantation, situated on the north side of the island of Oahu. This plantation was established in 1872, and it had been cropped twice annually until decreasing yields made rice culture on this land unprofitable except in years of exceptionally high prices. The yield from 37 acres of this tract for the 1907 spring crop amounted to 74,000 pounds of paddy, or an average of 2,000 pounds per acre. A part of this was produced on fertilized land, and a portion of the land had been fallowed for a season or two.

An acre tract of the poorest of these lands was set aside for these experiments, the object of which was to compare the relative value in economy of several complete fertilizers under different modes of application. The fertilizers in the first experiment were applied April 30, 1907, when the crop was about half grown, and they consisted of a special fertilizer made up of fish guano, acid phosphate, and sulphate of potash and magnesia, and a regular fertilizer which is more or less commonly used, which consisted of nitrate of soda, sulphate of ammonia, acid phosphate, and muriate of potash. These compounds were used alone and, in the case of the special fertilizer, in combination with sulphate of ammonia. They were applied by broadcasting on receding water, broadcasting and working into the soil to a depth of 2 inches, and broadcasting on the dry surface before reflooding.

The yield of paddy on the untreated plats was 2,888 pounds, the highest yield ever produced on this land without the use of fertilizer. It is thought possible that this large yield may have been due to the application of fertilizers to the adjoining plats. In making comparisons, however, the actual weights of crops were taken.

Where the special fertilizer was used and worked into the ground to a depth of several inches, 58.5 per cent gain, equivalent to $29.60 net profit per acre, was obtained, the cost of the fertilizer and labor involved in working it into the ground being deducted. Where the fertilizer was not worked into the ground an increase of 42.5 per cent was obtained, representing a net profit of $20.75. From this it will be seen that at a cost of $2 for working in the fertilizer an additional profit of about $10 was obtained. The special fertilizer yielded an increase of 35 per cent when applied alone, only 17.5 per cent less than when sulphate of ammonia was added to it.

In these experiments the regular fertilizer exerted very little beneficial effect, due probably to the low nitrogen content, which is the most striking deficiency.

The residual effect of the fertilizers is shown by the striking growth of the second crop on the treated plats.

EXPERIMENTS VI AND VII.

In conjunction with Experiment V two special nitrogen fertilizing experiments were undertaken on a field scale. Two forms of nitrogen were used, sulphate of ammonia at $72 per ton and nitrate of soda at $55 per ton, these prices representing the Honolulu quotations in November, 1907.

The sulphate of ammonia was applied at the rate of 75 and 100 pounds per acre and the nitrate of soda at the rate of 100 and 150 pounds per acre. All the applications were made at the same time, when the plants were a little more than half grown. The methods of application were those usually practiced by the Chinese growers, i. e., to broadcast the fertilizer upon the receding flood water just before the drying-off period, which in Hawaiian rice culture precedes the flowering stage of the rice plants.

The results of these experiments show that the sulphate of ammonia proved very efficient, and increases of 80 and 85 per cent were obtained from applications of 75 and 100 pounds, respectively. This gain was produced at the cost of $2.70 and $3.60 for material and resulted in a net profit of $35.15 and $36.50, respectively, for the different applications. The application of 100 pounds of sulphate of ammonia gave an increase of only 5 per cent over the application of 75 pounds per acre, amounting to a cash increase of only $1.35, which barely paid for the additional fertilizer. Where nitrate of soda was applied at the rate of 100 pounds per acre the gain was 21 per cent, equivalent to a net profit of $12. These results between the two forms of nitrogen are in practical agreement with those given in the pot experiments described above.

It seems reasonably certain from these and the other experiments that sulphate of ammonia is better suited to the rice crop than nitrate of soda, at least when both are applied in single applications to neutral soils. It is probable that better results can be obtained from nitrate of soda when it is applied two or three times during the growing season, particularly should the soils be acid. When it is remembered that the nitrogen in ammonium salts becomes available more slowly and gradually than in the nitrates and that nitrification takes place rapidly in saturated and submerged soils, there is probably a great waste when too large amounts of nitrate of soda are applied at one time, and an experiment has been planned to test this point in regard to the rice soils of Hawaii.

CULTURE EXPERIMENTS.

INFLUENCE OF AGE OF SEEDLINGS AT TIME OF TRANSPLANTING.

Throughout this report frequent reference has been made to the influence upon yield exerted by the age of seedlings at the time of transplanting. In the table on page 89 are given the results of an experiment in which seedlings 20, 25, 30, and 35 days old, respectively, were transplanted under otherwise identical conditions. All the seed had been sown on February 27 and the seedlings began to appear above ground on March 2.

The yield of Japan seed rice (No. 153) as influenced by age of seedlings at time of transplanting.

Experiment No.	Age of seedlings at time of transplanting.	Date of transplanting.	Date of flowering.	Date of maturity and harvest.	Yield from three 100 square feet cuttings.		Relative yields, experiment 1 taken as 100.	Calculated yields per acre.		Value of paddy per acre.[a]
					Paddy.	Straw.		Paddy.	Straw.	
					Lbs.	*Lbs.*		*Lbs.*	*Lbs.*	*Dollars.*
1	20 days old	Mar. 22	May 8	June 10	29.00	27.75	100	4,205	4,024	105.12½
2	25 days old	Mar. 27	...do	...do	25.50	24.50	87.93	3,697	3,553	92.42½
3	30 days old	Apr. 1	May 6	...do	22.25	22.50	76.72	3,126	3,263	78.15
4	35 days old	Apr. 6	May 5	...do	13.25	18.00	45.69	1,921	2,610	48.02½
5	20 days old (fertilized) ..	Mar. 22	May 9	...do	32.50	48.00	112.07	4,713	6,960	117.82½

[a] At $2.50 per 100 pounds.

By referring to experiment 1 it will be seen that the maximum yield was obtained from seedlings 20 days old at the time of transplanting and that a gradual and considerable decrease in yield resulted from each subsequent transplanting, the yields being almost in a direct diminishing ratio to the increased age of the seedlings. The importance of this phase of rice culture wherever the crop is transplanted, as it is in Hawaii and Oriental countries generally, can not be too strongly dwelt upon, since 10 days' delay in transplanting seedlings may decrease the yield of paddy almost one-half. It is to be remembered, however, that this loss, at least in this experiment, applies particularly to the quick-maturing varieties. Much less striking results were obtained from a preliminary experiment with a Hawaiian type of rice that required 140 days for maturity. The loss in yield due to the increased age of the seedlings at the time of transplanting was less than half that reported for the Japan type.

It will be noted in experiment 5 that in addition to being planted with 20-day-old seedlings the plat received 350 pounds of complete fertilizer, and that this addition resulted in increasing the yield only 12 per cent over the unfertilized plat. A part of each of the other plantings was likewise fertilized, and this resulted in a considerably greater gain in the plats planted to 25 and 30 day old seedlings. It is believed that the older seedlings having had their growth retarded were more largely influenced by the fertilizer than those which were transplanted at a more favorable season.

EXPERIMENTS IN BROADCASTING, DRILLING, AND TRANSPLANTING RICE.

An experiment was undertaken to test the relative value for Hawaiian conditions of two distinct methods of planting—the direct sowing of seed, as practiced in the southern United States, and the Hawaiian and Oriental custom of transplanting the seedlings. All the seed was sown on February 27. One lot was broadcasted at the rate of 50 pounds per acre and another lot of the same stock of seed drilled in rows 12 inches apart at the same rate per acre. When well established the seedlings in both cases were thinned out to a stand of approximately 200,000 plants per acre, to conform as closely as possible with the stand of transplanted plants.

The results of this experiment are shown in the accompanying table:

Relative yields from broadcasted, drilled, and transplanted Japan seed rice (No. 153).

Experiment No.	Method of culture.	Date of germination.	Date of flowering.	Date of maturity and harvest.	Height of plants.	Average number of fruiting culms per plant.	
						Primary.	Secondary.
					Inches.		
1	Seed broadcasted, harrowed in 1 to 2 inches deep, and flooded	Mar. 2-5	May 1-5	June 6	23-24	2-3	1-2
2	Seed drilled in 1 to 2 inches deep (rows 12 inches apart) and flooded	....do	.....do	....do	25-28	2-3	1-2
3[a]	Seedlings 20 days old at transplanting	Mar. 2	May 8-10	June 10	32-34	6-8	1-3
4[a]	Seedlings 35 days old at transplanting	....do	May 3-5	....do	20-22	2-4	1-2

Experiment No.	Method of culture.	Yield from three 100 square foot cuttings.		Calculated yields per acre.		Value of paddy per acre.[b]
		Paddy.	Straw.	Paddy.	Straw.	
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Dollars.*
1	Seed broadcasted, harrowed in 1 to 2 inches deep, and flooded	12.25	17.95	1,776	2,501	44.40
2	Seed drilled in 1 to 2 inches deep (rows 12 inches apart) and flooded	13.50	15.50	1,958	2,393	48.95
3[a]	Seedlings 20 days old at transplanting	29.00	27.75	4,205	4,024	105.12½
4[a]	Seedlings 35 days old at transplanting	13.25	18.00	1,921	2,610	48.02½

[a] Taken from preceding table.

[b] At $2.50 per 100 pounds.

It will be seen from experiment 3 that the seedlings 20 days old at the time of transplanting yielded more than either the broadcasted or drilled seed, the increased cash value being more than $50 per acre for the transplanted stock. On the other hand, when the seedlings were 35 days old at the time of transplanting the yields were about equal to those from direct sowing.

The differences in yield due to broadcasted or drilled seed are hardly sufficient to warrant definite conclusions. It is believed, however, that greater uniformity of stand and economy of seed are obtained by drilling.

The cost of transplanting an acre of rice in Hawaii does not exceed $6. Four men can transplant an acre per day, setting out 50,000 clumps, consisting of from 4 to 8 seedlings each.

From the above table it is readily seen that under present Hawaiian conditions the transplanting method in rice culture is amply justified.

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HAWAII AGRICULTURAL EXPERIMENT STATION
E. V. WILCOX, Special Agent in Charge.

ANNUAL REPORT
OF THE
HAWAII AGRICULTURAL EXPERIMENT STATION
FOR
1908.

UNDER THE SUPERVISION OF
OFFICE OF EXPERIMENT STATIONS.
U. S. DEPARTMENT OF AGRICULTURE.

HONOLULU:
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[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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Gt
Lt-Col. T. M. Spaulding
1-16-31

LETTER OF TRANSMITTAL

Hawaii Agricultural Experiment Station,
Honolulu, Hawaii, January 4, 1909.

Sir: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year 1908.

Respectfully,

E. V. Wilcox,
Special Agent in Charge.

Dr. A. C. True,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. True, *Director.*

Publication authorized.
James Wilson,
Secretary of Agriculture.

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ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1908

SUMMARY OF INVESTIGATIONS.

By E. V. Wilcox, *Special Agent in Charge.*

The investigations described in the accompanying report were all begun under the supervision of the former special agent in charge, Mr. Jared G. Smith, who severed his connection with the station at the end of the fiscal year. The report, however, was prepared under the direction of the present special agent.

During the year considerable attention was given to the improvement of the general appearance of the station grounds and buildings. A number of old and unsightly structures were torn down and replaced by others more serviceable and of better appearance. One structure was erected to contain a tool house, seed storehouse, and carpenter shop, on the ground floor, and a rice laboratory in the second story. An addition was made to the stable, in which a blacksmith shop and implement shelter are provided. The experimental grounds and pastures were surrounded with new and substantial fences, and about 5,000 feet of new pipe line was laid for irrigation purposes. In addition to these changes and alterations, an old office building was torn down, and a new 5,000 gallon water tank was erected near a 2-acre rubber plantation on the slope of Tantalus at an elevation of about 700 feet.

The leases held by the station on lands for growing rice, cacao, and bananas have been given up, except for the rice trial fields, which are conveniently situated and are in excellent tilth. The other leases were abandoned on account of the distance of the lands from Honolulu and the difficulty of supervising the experiments under the present appropriation.

During the year the station published Press Bulletin No. 20, on The Introduction of Top-Minnows into the Hawaiian Islands, by D. L. Van Dine, and the following Bulletins, in the regular series of the station: No. 14, Marketing Hawaiian Fruits, by J. E. Higgins; No. 15, Cultivation of Tobacco in Hawaii, by Jared G. Smith and C. R. Blacow; No. 16, The Ceara Rubber Tree in Hawaii, by Jared G. Smith and Q. Q. Bradford; and No. 17, Hawaiian Honeys, by D. L. Van Dine and Miss Alice R. Thompson.

The correspondence of the station related chiefly to the supervision of field experiments, the distribution of economic plants to the islands, the introduction of new plants or varieties, advice regarding cultural details of various crops, the control of insect and fungus enemies, and suggestions to prospective settlers in reply to inquiries regarding prospects for farmers in these islands. Various localities on all of the important islands were visited during the year by the station staff, and the horticulturist made a trip to the mainland in the investigation of fruit shipping. The station assisted in a horticultural and agricultural exhibit in coöperation with the Hawaiian Poultry Association. Members of the station staff also gave lectures at meetings of the farmers' institute and in connection with the work of the College of Hawaii.

CHEMICAL INVESTIGATIONS.

The principal chemical work of the year was of an analytical nature and was concerned chiefly with the determination of the composition of paddy, rice straw, and rice grain. This work was done in coöperation with the rice investigations of the station. Analyses were made of several varieties of rice, particularly imported Japan rice, Japan rice grown in Hawaii, and Hawaiian Gold Seed rice. The analyses showed that the claims which have been made for the greater nutritive value of imported Japan rice, as compared with Japan rice grown in Hawaii, are not well founded. In fact, Japan rice grown in Hawaii appears to be slightly more nutritious than that imported directly from Japan. The composition of rice straws is not quite so constant as that of rice grain. It was found that dry-land rice takes up less lime and more phosphoric acid than rice grown under submerged conditions.

Analyses were also made of rice hay as fodder, Rhodes grass, cassava waste, wheat hay, cowpea, jack bean, pigeon pea, castor pomace and peanut meal. In connection with pineapple investigations, analyses were made of soils from pineapple fields. As a rule, the lime content was found to be low. Potash and available phosphoric acid were also somewhat deficient. In some cases, the lime content was higher than that of magnesia, while in other cases the conditions were reversed.

Analyses of drainage water, from lysimeter experiments, showed that the use of ammonium sulphate as a fertilizer causes loss of lime in the soil. Analyses were made of wax left in slum-gum and also of koa bark and ohia bark. In a pot experiment with fertilizers for Hevea rubber, it was found that sodium nitrate gives good results, while acid phosphate affects rubber trees unfavorably.

RUBBER.

The chief results from the rubber investigations of the year were published in Bulletin 16. During the last quarter of 1907, experiments were made in planting Hevea rubber seeds. They germinated and grew best when the shell had been removed and the seeds planted in clean sand. The herring-bone system of tapping on Ceara rubber trees gave quite favorable results. In some experiments on Kauai it was at times found difficult to coagulate the latex. This was accomplished, however, by the addition of hydrogen peroxide and sulphuric acid. As many as thirty consecutive tappings were made by excising a thin slice of bark from the old wound, and a good flow of latex was obtained during the whole period. The use of a water bag, or an ammonia bag, was found to increase the relative amount of first-grade rubber as compared with scrap rubber. By tapping yearling trees it was found that the yield differed greatly. This point may be of value in indicating which trees should be cut out, and which ones should be kept in the plantation to increase the total yield.

ENTOMOLOGICAL INVESTIGATIONS.

The insect collection and reference library have been considerably increased and a steady improvement has been made in the systematic arrangement of this material. The chief lines of entomological work during the year were studies of insects affecting domestic animals, pineapples, cotton, mangoes, and apiculture. A survey was made of the cattle ranges for the purpose of determining the status of the horn fly. This insect is perhaps more injurious in these islands than on any part of the mainland, occuring in immense swarms and attacking not only cattle, but also other animals. An attempt is being made to introduce natural parasites of the horn fly to supplement direct and indirect insecticidal measures, such as treatment of cattle dung and spraying infested cattle. The problem is recognized as a difficult one on account of the universal distribution of the pest in the islands and the half-wild conditions under which range cattle live. In the case of dairy herds and work oxen, the problem is somewhat simpler.

Great losses have been suffered from sheep-maggot fly (*Calliphora dux*), which has changed its habits so as to become a parasitic insect. The insect deposits its eggs on wounds, in areas infested by the sheep-scab mite, or in soiled wool. The larvae make their way into the tissues underneath the skin, causing suppuration and septicemia, followed by death, unless a suitable treatment is administered. The investigations thus far made indicate clearly that in order to control this pest it is absolutely necessary that all sheep carcasses should be promptly buried. In this way the excessive multiplication of the sheep-maggot fly will be checked, for the favorite breeding ground of the pest is in carcasses. It has also been found necessary to destroy eggs and maggots in infested pens and corrals.

The entomologist has devoted considerable time to the investigation of apicultural problems and the encouragement of bee raising. The honey crop of the islands for the year will amount to nearly 1,000 tons. Available locations for apiaries have been largely taken up, but there is still room for extension. A survey has been made of the honey-plants of the islands and a number of new honey-plants, which are also useful for other purposes, have been introduced. The present list of good honey-plants in the islands is extensive. In order to prevent the possible introduction of foul brood, an act was passed by the Territorial legislature providing for the careful inspection of imported bees and honey.

The great extension of the pineapple industry has called attention to certain injurious insects, particularly scale insects and mealy bugs. A number of fumigation tests were made in which effective doses were determined for fumigating pineapple suckers and offsets before planting, and also for treating pineapple fruits before shipment to the mainland. As a result of the recommendations based upon these experiments, the shipment of fresh pineapples to the mainland has been accomplished with striking success.

The station has for the time closed its work in the investigation of mosquitoes, the important facts concerning their life history and suppression having been determined and published. The control of mosquitoes is now in the hands of the Territorial authorities.

A revised list has been prepared of the injurious insects of Hawaii, and also of the additions to the entomological library relating to Hawaiian entomology.

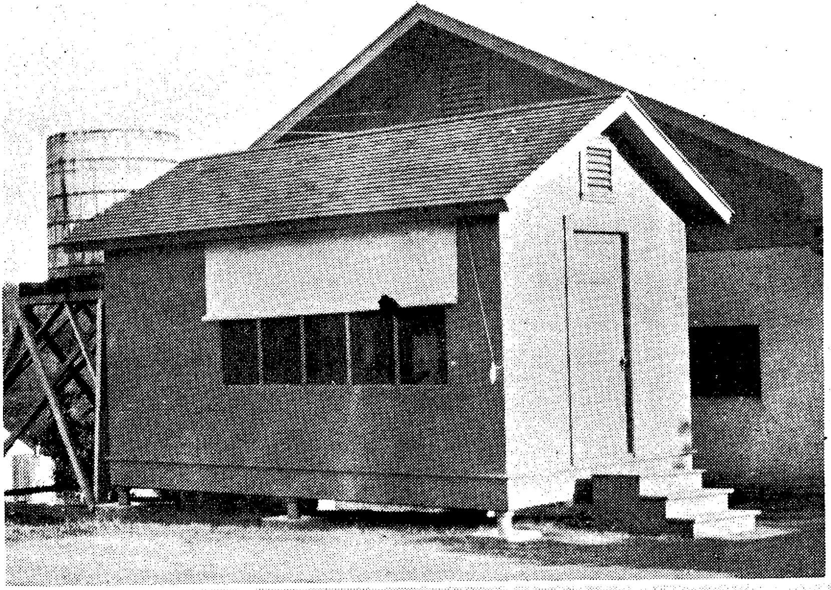
A new insectary has been erected and equipped (see Pl. I). It is built on sewer pipe piers set in cement basins filled with water. The steps are separate from the building and the building is insect proof.

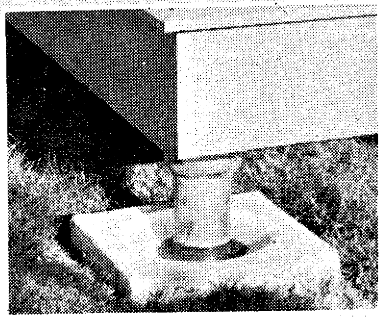
HORTICULTURAL INVESTIGATIONS.

The chief work of the year was done in studying the problems of shipping fresh fruit, including pineapples, avocados, papayas and bananas. The demonstration of the possibility of shipping pineapples and avocados as far as Chicago was followed by commercial shipments to various inland cities. The great increase in the acreage of pineapples has called attention to the necessity of further developing the fresh-fruit markets, and the results thus far obtained are encouraging.

A rearrangement of water pipes in the orchards of the station has made it possible to irrigate more conveniently and satisfactorily. Much attention has been given to cover crops for

PLATE I.


1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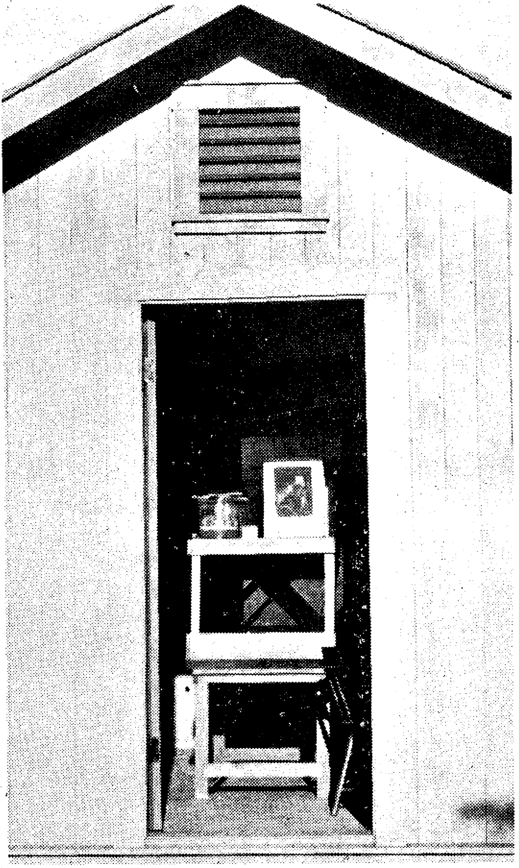
3

Fig. 1. New Insectary built on sewer pipe piers resting in cement basins filled with water.
Fig. 2. Detail of pier. Fig. 3: Interior showing breeding cages.

orchards. On steep grades cover crops are necessary to prevent washing during the occurrence of heavy showers. Since growth continues during the whole year, it is necessary to keep the ground free from the cover crop for a short distance around each tree. The cover crops chiefly used so far are cowpeas, pigeon peas, and jack beans. Cowpeas make the quickest growth, but are quite susceptible to the attacks of insects. Pigeon peas require longer to reach maturity. The jack bean makes a lower growth but is a good cover and is exceptionally free from insects. The ordinary insect pests have been kept in check by repeated spraying with kerosene emulsion; and by the use of a sticky mixture to keep ants from the trees.

The rough lemon has proved to be an excellent stock for use in establishing citrus orchards. An extensive budding test is in progress. More than forty varieties of bananas are growing on the station grounds. It has been found necessary to establish a nursery to supply the demands which are made for certain varieties; otherwise the experimental work would have been interfered with. Several of the varieties now grown at the station were imported from Porto Rico, and the native varieties have been collected from various parts of the Territory.

In work with mangoes, 80 per cent of the buds of Alphonse mango have grown. The results are not always so satisfactory with all varieties. It has been shown that budding must be done in the early part of the season of active growth. Mango trees two or three years old may be safely transplanted. In experiments at the station nearly all the trees transplanted at that age quickly started into growth whether the roots were freed from soil in the process of transplanting or had been enclosed in a ball of wet earth. Inarching appears to be the surest means of propagating fine varieties of mangoes, but is rather more expensive than budding. (See Plate II). In shipping experiments with young mango trees, it was found that a large percentage of them will be lost in transit unless care is taken to select trees with firm wood and a dormant terminal bud.

Attention has been given to the study of the flowering period of the mango, which appears to vary from year to year. The station has added more than three hundred varieties of plants to its horticultural collection during the year. Of this number, special mention should be made of henequen, pineapple varieties (from the Department of Agriculture), wampi fruit, cherimoya, litchi, camphor, and the Victor variety of roselle. A constantly increasing call is made for plants and cuttings for distribution in different parts of the islands; and the station has complied with these requests in so far as the facilities and experimental work would allow.

The horticulturist has given considerable attention to the encouragement of deciduous plantings at high altitudes on the island of Hawaii, and to a study of the problems connected with the production of red peppers.

RICE INVESTIGATIONS.

General interest in rice investigations is increasing from year to year, and the expert in charge of this work has been called upon for advice and technical help in the fertilization, culture, harvesting, milling, and other processes connected with rice production.

A variety known as No. 19, originally from Ceylon, has proved to be an exceptionally heavy yielder and is especially adapted as an export crop for consumption by Chinese upon the mainland. It is best used as a fall crop. Variety No. 65, an Egyptian rice, has given excellent returns in dryland culture. The yield is satisfactory. The variety promises well as a hay crop on account of its smooth glumes and large yield.

During the year an elaborate series of fertilizer experiments was carried on with rice. It was shown that when fertilizers are applied to rice after the crop is two-thirds grown the first crop receives the least benefit, and the succeeding crop shows the greatest residual effect of the fertilizer. If, on the other hand, the fertilizer is applied before planting the first crop of the season, this crop takes up nearly all of the fertilizer, while the second crop receives little or no benefit. In pot experiments it was shown that there is no residual effect of nitrate of soda upon the second crop, even though the application be made at a late stage of growth of the first crop. The greatest residual effects upon the second crop have been produced by the use of sulphate of ammonia and fish guano. Experiments in pot and field culture have demonstrated that rices which mature slowly receive the most benefit from fertilizers which become available slowly, for example, sulphate of ammonia.

In direct fertilizer experiments, in which the residual effect upon the second crop was disregarded, a comparison was made between sulphate of ammonia, lime nitrogen, and nitrate of soda. The sulphate of ammonia doubled the yield, as compared with unfertilized rice, and gave much better results than either lime nitrogen or nitrate of soda. The last named source of nitrogen appeared to give little benefit in increased growth, except when applied after the crop was two-thirds grown. In dry-land culture of rice muriate of potash produced striking results. The experimental results, obtained in pot and field cultures, have attracted much attention and the station has been called upon to plan a scheme for the systematic fertilization of a large rice plantation. This plan has already been put into effect.

The lack of natural hay crops in the islands, and the consequent heavy drain upon the resources of farmers in buying imported hay, suggested to the station the desirability of a study of upland rice as a hay crop. It has been found that $2\frac{1}{2}$ inches of water per week, during the growing season, is necessary to insure a paying crop. Our experiments have also demonstrated the desirability of deep and thorough tillage and light seeding.

Salt marsh rice has also been tested as a hay crop. Rice grown on salt marshes is inferior in quality of grain, but has been demonstrated to be an efficient substitute for imported hays. It is believed that a portion of the $250,000 annually paid for imported hays may profitably be devoted to the production of a home crop of salt marsh rice for hay. The total weight, in a green condition, of salt marsh rice is about 14,000 pounds per acre, valued at $73. No difficulty has been experienced in securing such hay in a well cured condition. The feeding experiments thus far made with this material have shown that it is relished by cattle and horses and that its nutritive value is satisfactory.

EXPERIMENTS WITH MATTING SEDGES AND RUSHES.

For two years experiments have been carried on with Chinese mat sedge (*Cyperus tegetiformis*), and Japanese Bingo-i mat rush (*Juncus effusus*). Three harvests have been made of these matting plants at the rice trial grounds and a large planting has been made on the windward side of the island of Oahu. The yield from the Chinese mat sedge has been at the rate of 8,700 pounds per acre of the 60-inch length; 5,700 pounds of the 48 to 60-inch length; and 5,200 pounds of the 30 to 48-inch length. The crop requires from six to seven months from planting to maturity, and five months for the rattoon crop. Sample reeds of the Chinese matting sedge were forwarded to a factory on the mainland, and flattering reports were received as to their quality. A small sample of woven mat was made from the material. The greatest difficulty in the way of making this crop a financial success consists in the fact that each reed must be split. With the invention of a machine for doing this work, the crop promises to be profitable and can be grown in brackish marshes, which would otherwise be useless. The Japanese matting rush does not require splitting and is improving with each crop, but has not yet attained a sufficient length for profitable handling.

COTTON EXPERIMENTS.

Fifty years ago Sea Island cotton was grown in these islands, but the industry was allowed to lapse. The station has been experimenting with Sea Island and Caravonica cottons with striking results. The yield is high, the fiber of good length, strength and luster, and the percentage of lint ranges from 30 to 40. All varieties of cotton thus far tested grow as perennials in these islands, and the shape of the trees and the time of maturing the bolls may be controlled by pruning.

MISCELLANEOUS CROPS.

Several varieties of soy beans have been grown for use as fodder, green manuring, and human food, particularly in the Japanese product, Miso. The yields have been very encouraging. About 500 tons of soy beans are annually imported from Japan, and the demand is increasing. These beans are sold in Honolulu for $3 per 100 pounds. The market can easily be supplied by home production.

Peanuts have yielded gratifying results in various localities. On the trial grounds of the station a number of varieties have been grown, including Spanish, Bunch Jumbo, Running Jumbo, and Virginia Running.

REPORT OF THE ENTOMOLOGIST.

By D. L. Van Dine.

INTRODUCTION.

The entomologist visited during the year the islands of Hawaii, Maui, Kauai, Molokai, and all the outlying districts on the island of Oahu. Two trips were made to the island of Molokai, where the opportunity for observations on bee-keeping and live-stock insects are exceptionally favorable.

The office record relating to injurious insects in Hawaii in general and to particular groups or species in detail, the collection, and the reference library show a steady growth. This material will be so arranged that the information at hand will be available for use without loss of time, and further, so that accessions may be made without adding confusion. It is the purpose to work toward a systematic arrangement which will permit the use at any time of the results of entomological investigations throughout the world in so far as they are applicable to the peculiar climatic and economic conditions of Hawaii.

The important lines of work during the year were investigations relating to the insects affecting live stock and bee keeping. On Oahu, further work was undertaken on the insects affecting pineapples, cotton, and mangoes.

The insects affecting live stock in Hawaii are second only in economic importance to those injurious to sugar cane. Some of the species of this group of pests are known to stockmen, and the status of one especially, the horn fly, is well understood. There are several live-stock pests recorded from Hawaii the local status and occurrence of which have not been definitely ascertained, as for example the horse botfly, the stable fly, and the sheep head-maggot fly; and there are still others which are not even recorded, as the two recently determined species of blow or maggot-flies affecting sheep. An effort is being made on the natural-enemy phase of the control of the horn fly and there is a possibility of relief from this source, but the general statement can be made that as a group the insects affecting live stock in Hawaii exact their heavy annual tax unhindered and, in some instances, unrecognized.

The investigations relating to the insects affecting live stock in Hawaii were undertaken jointly by the writer and Dr. V. A. Nörgaard, Territorial veterinarian and veterinary inspector of the Bureau of Animal Industry of the U. S. Department of Agriculture. The writer is responsible for the entomological work and Dr. Nörgaard has in charge the pathological investigations relating to the subject. The notes on the horn fly and the sheep-maggot fly are taken in the main from a joint report to the Hawaiian Live-Stock Breeders' Association.*

The interest at present being shown in the production of cotton in these islands will necessitate some consideration of the insects affecting the cotton plant. A large number of insects attack cotton, and the combined effect of their injuries on the growth of the plant and the quality of the staple offers a more or less serious menace to the success of cotton growing.

The worst injury is done by a small boll worm (larva of a Tineid moth, *Gelechia gossypiella*), which seems to be identical with the "pink-spotted boll worm" affecting cotton in India. The Japanese beetle (*Adoretus umbrosus tenuimaculatus*) skeletonizes the leaves. A mealy bug (*Pseudococcus filamentosus*) produces considerable injury on young plants and about forming buds and bolls, and the tender foliage and blossoms suffer from the attacks of an aphid. The cotton boll worm (*Heliothis obsoleta*) of the southern United States is found on tobacco and corn in Hawaii, but if cotton planting becomes extensive its spread to this crop may be anticipated.

The determination and study of the life histories, habits, and injuries of these pests will be a feature of the coming year's work.

As in the past, the writer is pleased to record the courtesies received from co-workers in Hawaii and abroad, and would point especially to the aid and advice given by Dr. L. O. Howard, Chief of the Bureau of Entomology of the U. S. Department of Agriculture. The writer would mention here also the kindly suggestions and helpful support received from Mr. Jared G. Smith, Special Agent in Charge of this station.

THE HORN FLY.

(*Haematobia serrata*).

The horn fly was introduced into Hawaii with shipments of cattle from the western coast of the United States to the island of Oahu during 1897. Within a year it had spread to all the other islands. In the ten years that have since elapsed, it has bred uninterruptedly, and the annoyance caused by its blood-sucking habit has been felt during this time by all the thousands of cattle on Hawaiian ranches. The smaller dairy herds have likewise suffered. Horses are bothered to some extent by the fly, especially when near cattle. Recently, Nörgaard has pointed out the complication of sheep-scab and horn fly injury on sheep.* To this complication has been added, later, that of the maggot flies, which in many cases take up the work of destruction in connection with, or subsequent to, the injuries caused by the scab mite and horn fly.

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* Report of the Division of Animal Industry, Rept. Bd. Commrs. Agr. and Forestry, Hawaii, 2 (1905,) pp. 171, 211,212.

While the horn fly in the United States and Canada causes more or less loss to the live stock and dairy industries, it is checked in these countries by two distinct seasons, a cold and wet and a hot and dry season. As warm wet weather is required for the continuous development of the horn fly, it would seem that the Hawaiian Islands offer an especially favorable breeding ground for this pest. The horn fly requires but little rainfall, and finds here an equable temperature, varying but slightly with the seasons, and at no time detrimental to its propagation. Prolonged drought will check it, ordinary dry weather retard it, but climatic conditions which might be called destructive to it rarely occur here. It is, therefore, little wonder that, once introduced here, it required but a short time to spread all over the Territory and to multiply to such an extent as to make Hawaii compare with the worst infested sections of the mainland.

The two lines of control that are offered for the horn fly are, as with all insect pests, preventive and curative measures. Prevention includes the destruction of the larvae in cattle dung by direct measures or by the introduction of natural enemies that will feed upon them. Curative measures include protection of the cattle from the attacks of the fly or the wholesale destruction of the adult flies. All of these methods of control have received serious consideration as evidenced by the many reports dealing with the treatment of cow dung to destroy the breeding place of the larvae, the introduction of natural enemies from one country to another, the spraying of cattle with repellent mixtures and trapping and spraying experiments to destroy the adult fly. These various methods and their application must be considered with reference to Hawaiian conditions. The use of repellents does not appear feasible in Hawaii except in the case of our dairy herds, and even there they should be used only in conjunction with preventive measures for the destruction of the larvae in the dung. Prevention, therefore is the keynote to the control of the horn fly.

The large areas comprising the cattle ranges and the semi-wild condition of the herds give emphasis to the idea that the only hope of permanent relief for beef cattle lies in procuring effective natural enemies. The serious menace that faces cattle raising so long as the horn fly ravages remain unchecked, justifies the continuation of efforts to procure such enemies from abroad, and to establish and encourage promising species already within the Territory. This phase of control work, however, should not deter the stockmen from doing their share toward the suppression of the pest, as natural enemies do not become a factor until they are obtained and established. In other words, while supporting investigations relating to this work, ranchers should not allow the possibility of direct measures of control to pass from their minds.

Great benefit could be derived were it possible to destroy wholesale the adult flies on cattle in the fattening paddocks. It is a well-known fact that cattle in a fattening paddock cannot be finished for market while the flies are bad even when their feed is abundant. It would be highly desirable to submit such cattle to one or two dippings or sprayings, providing such operations would afford perfect rest to the cattle for at least a month or six weeks before going to market. However, it is only where the application of such remedies can be made on a scale promising returns in proportion to the time and labor expended that they can be considered.

The habits of horn flies are such that they never fly any great distance from the cattle or leave them for any length of time. Whether they rest on foliage or grass in any numbers is not known, but it is safe to conclude from the observations made by many investigators and from our own experience that when all of the animals in the pasture are rounded up, nearly all of the adult flies are around the animals, including the cow-ponies. As the flies are very light and as they are easily carried by the wind, to free a pasture from adult flies would require that all animals be rounded up and driven with the wind out of the pasture and then put through the dip or spray and back into the same pasture against the wind. To prevent any of the flies returning with the cattle it might be well to build a funnel-shaped canvas-covered guard at the entrance to the place of treatment and a long brush-covered chute at the exit. Two weeks after the first treatment the operation should be repeated, in order to destroy the horn flies which have since developed. It is a safe conclusion that all of the flies which are left behind and which are not destroyed in the treatment will assemble on or around the horses of the cowboys and annoy them greatly, and if any cowboy returns to the (presumably) clean pastures, thousands of flies will follow.

Still better results might be obtained if the pasture to be freed from flies could be left empty for two to four weeks after the cattle and flies have been removed, but until something definite is known as to what becomes of horn flies which are hatched in the pasture where there are no animals to feed on, how long they can live without food, and what distances they will travel in search of food, nothing certain can be said in regard to the length of time the pasture should be allowed to rest, to completely free it from the flies. From deductions made from observations of other species, it is, however, safe to conclude that the above-mentioned period, two to four weeks, would be sufficient for the great majority of them to disappear.

To attend to the droppings of animals, however small the number or however easy the method, is practically out of the question except on dairy ranches. It has been estimated that perhaps 50 per cent of the developing flies can be found in the dung in the vicinity of watering places, pens, and shady retreats.

The cakes are found in greater numbers and more eggs are probably deposited in them than in those which are dropped over the range. The same applies to cattle yards near dairies or farms where the animals are being held at milking time. Appropriate treatment of the dung in these places would destroy a proportionately large number of larvae.

A still less expensive method of scattering the dung in yards and pens is to allow a number of pigs to run with the cattle. In their efforts to obtain undigested particles of food they will effectively destroy the cakes as breeding places for the fly larvae, at least during the dry season. This is especially noticeable in feed yards on the mainland where hogs sometimes follow cattle, and, to a certain extent, in the algaroba belts of these islands.

That the prevalence of insect pests in the Territory is due, to a great extent, to the almost total absence of insectivorous birds, can not be doubted. The writer has conferred with Prof. H. W. Henshaw in regard to the introduction of birds, particularly those that are destructive to flies. Prof. Henshaw is familiar with the conditions in these islands and offers every encouragement to the hope that desirable birds can be found. The necessity of studying carefully the feeding habits of any bird introduced, before it is liberated, has been pointed out by all who have been consulted, and for this purpose an observational aviary will be established in connection with the Pacific Scientific Institute. The station has arranged to work in coöperation with Mr. W. A. Bryan, President of the Pacific Scientific Institute, in its efforts to secure valuable insectivorous birds.

THE SHEEP-MAGGOT FLY.

(*Calliphora dux*).

The Hawaiian sheep-maggot fly was first collected by the writer on the island of Molokai. It was forwarded to Washington for determination, and Mr. D. W. Coquillett, of the Bureau of Entomology, identified it as the above-named species, which had not hitherto been recorded from the Territory of Hawaii and is here for the first time known as an animal parasite. No reference can be found in the literature of animal parasitism, to a similar case of a practically obscure species, supposedly infesting only dead animal tissue, suddenly adapting itself to living animals with such serious results. The outbreaks that have thus far come to our notice are sufficient to place the species in the front rank of the pests with which stockmen in Hawaii will have to deal, especially in sheep raising.

The fly has probably been in this Territory for a comparatively long time, and, while details have not yet been secured, enough information is at hand to show that sporadic cases of "blown" sheep have occurred in past years without epidemics resulting from them. An understanding of our own species has been extended by references to similar injury to sheep from different, though related, species in the British Isles and Australia. The problem is far from being solved, and demands extended and detailed study before definite conclusions can be reached.

The fly itself can be recognized as the species with bluish green metallic coloration which breeds wherever decaying flesh is left exposed. On the ranches, where it occurs, it is always attracted in numbers when animals are slaughtered. The fly will "blow," that is, deposit its eggs, on any exposed meat or in any wound, but preferably when the wound has become foul. Its development as a parasite of sheep in this Territory began by the flies blowing the scars from sheep scab which had been irritated to bleeding by the horn fly. The attack of the blow fly, combined with the sheep-scab and horn fly injury, in some instances resulted in the death of the animal; and from the carcasses of the dead sheep innumerable flies developed. From this source the fly became epidemic and began to blow not only the sheep-scab wounds, but also dead wool or wool fouled in any manner, especially on sheep or lambs suffering with scours.

When the eggs are deposited on wool, the resulting maggots, which appear within twenty-four hours, work down through the wool to the body. They do not attempt to penetrate the unbroken skin, as do the screw-worm maggots, but work in a constantly moving, intermingled mass over the surface, causing irritation, which brings about inflammation and ulceration, on the products of which the larvae feed. Later, the wool drops off, leaving a festering ulcer that is constantly being reblown, while masses of eggs are also being deposited in the filthy wool surrounding the sore. Such an infestation, of one week's standing, will contain maggots in all stages of development, as well as unhatched eggs. When the skin is completely destroyed, the maggots penetrate with ease in all directions under the skin, forming fistulas and sinuses, and the animal dies from septicemia or from exhaustion.

As the maggots mature, they drop to the ground and pupate in the soil. The life cycle does not extend over more than three weeks and the larvae or maggots develop in less than ten days.

No remedy has yet been found that in one application will kill the maggots, disinfect the wound, and prevent reinfection. The present treatment is a dual one. All loose and foul wool is removed and destroyed and the wound and surrounding skin are treated with a mixture of chloroform and kerosene oil in the proportion of 1 to 10. This dislodges and kills all the maggots. An application is then made, with a brush, of a mixture of flowers of sulphur and Stockholm tar in equal proportions by measure, to which has been added a small amount of sperm oil (1 quart to 5 gallons of the mixture) to give elasticity to the resulting crust. The wound heals well under the crust, which not only protects it from being reblown, but also from attacks by the horn fly. With the exception of aggravated cases, one treatment is sufficient, but the treated animals must be watched closely, as they are likely to bite off the crust on account of the itching which accompanies the healing process.

By far the most important measure in dealing with an epidemic of maggot flies is to locate the affected animals, and this is, to say the least, extremely difficult when the animals are on the open range or in large pastures, and with sheep which are not accustomed to being herded it is impossible to get near enough to them without rounding up the entire lot and examining them in a corral. On the open range or in pastures containing perhaps 10,000 acres, only the worst cases can be seen, when they lag behind the herd from weakness. Such animals may just as well be killed and buried on the spot, in which case care should be taken to bury them deep enough to exclude the possibility of newly hatched maggots working down to them, as the stench which rises to the surface from a carcass in a shallow grave will cause numerous flies to deposit their eggs on top of it. The writer has seen such a grave, from which the egg masses could be scooped up in double handfuls. This fully illustrates the necessity for disposing effectively of all dead animals, especially during an epidemic.

Equal care must be taken to destroy all eggs and maggots in pens where affected animals are being tagged or treated. We have seen the ground in such a pen completely covered with newly hatched flies, sitting so close together as to lend a greenish sheen to the surface. Two or three weeks before this observation was made, a number of sheep had been treated there for maggots. The affected animals should be treated and sheared on a piece of canvas or a wagon-sheet and the rubbish collected and burned.

BEE KEEPING.

The year has been marked by a decided impetus to the bee-keeping industry. The last estimate of the annual crop was 600 tons. This season's crop will amount to nearly 1,000 tons. Two reasons can be assigned for this increase, (1) a normal flow from the algaroba, and (2) the extension of the industry, i. e., increase of the number of colonies and establishment of new locations. The number of colonies at present in the Territory is not far below 20,000. Two companies have begun operations on the Island of Hawaii (the largest island of the group) and one concern at least on account of the many desirable locations available is in a position to increase rapidly. On the Island of Kauai the greatest extension of the industry has occurred and two corporations are well established. The Island of Oahu is practically the only island where the available territory is occupied, with the possible exception of the lee side and west end of the Island of Molokai. One corporation is now well established on the Island of Maui and an increase has been made on this island with the opportunity for still further increase. The honey and wax crop of the islands is worth in round numbers $100,000, and the next few years will see the production increased by at least one-half.

A survey of the available bee plants, apiaries, and locations for apiaries, which is under way, has been completed for the Island of Molokai. Several trees and plants of value as bee pasturage have been introduced, and some of these are now established. In regard to the introduction of plants, the general policy has been that only plants possessing a dual value will be considered, that is, plants which not only produce nectar but are of value as forage or timber. This will obviate the danger of establishing in the Territory any plant which might become noxious. The lantana is a great object lesson in this respect. The following is a list of the plants that produce nectar in Hawaii:

THE SOURCE OF HONEY IN THE HAWAIIAN ISLANDS.

FOREST TREES.

Algaroba, keawe (*Prosopis juliflora*). This tree is the most abundant and important nectar-producing plant in the Hawaiian Islands. The principal apiaries are situated along the leeward coasts in the shelter of the algaroba forests. The honey is of a high grade.

Texas mesquite (*Prosopis glandulosa*) was found growing in the dooryard of Mr. C. C. Conradt, Pukoo, Island of Molokai. Seedlings are being propagated at the station. This tree was introduced from Texas by Mr. Conradt several years ago.

Ohia lehua (*Metrosideros polymorpha*) produces a particularly high grade of honey. Locations for apiaries as a rule are somewhat inaccessible. One location on the Island of Molokai is within the ohia lehua belt.

Various species of acacia (black wattle, koa, etc.) occur in mountainous districts.

Various species of eucalyptus are found in mountainous districts.

Wiliwili (*Erythrina monosperma*) occurs in gulches on Molokai and Oahu.

Rose-apple (*Eugenia jambosa*) and Mamani (*Sophora chrysophylla*) are found in higher forest belts.

Catalpa (*Catalpa speciosa* and *C. bignonioides*) was introduced by Mr. Jared G. Smith, April, 1902, from the Missouri Botanical Gardens. The seeds were distributed to the Makawao district and Puunene on Maui; to the Moanalua Gardens on Oahu; to Makaweli on Kauai, and to Hamakua and Kohala districts on Hawaii. No reports are on file at this station as to the results of this introduction.

Logwood (*Haematoxylon campechianum*) is found in dooryards. Two trees are growing in the grounds of Oahu College and one in the grounds of Lunalilo Home, Honolulu. Seedlings are now being propagated at the station. The honey produced by bees from this tree is reported to be the finest table honey in the world. The propagation and distribution of the logwood throughout the Territory would be of great value to bee keepers, and the wood furnishes the logwood dye of commerce.

The black mangrove of Florida was introduced by Mr. Jared G. Smith from Southern Florida, for the purpose of holding the mud flats along the coast of Molokai near Kaunakakai from washing. The introduction was made several years ago and the trees are now well established at the above mentioned place. The tree is a valuable honey plant. The station has also secured the Philippine mangrove, a tree suitable for similar locations but possessing greater value as a timber tree.

FRUIT TREES.

Various citrus species (orange, lemon and lime), avocado (*Persea gratissima*), banana (*Musa* spp.), guava (*Psidium* spp.), loquat (*Eriobotrya japonica*), and tamarind (*Tamarindus indica*).

PASTURE PLANTS.

California bur clover (*Medicago denticulata*) was introduced on Maui in 1882 by Mr. C. R. Blacow, and is now found generally on the ranches of the islands.

Carpet grass (*Lippia repens*) is growing on grounds of the station.

Alfilaria or filaree (*Erodium cicutarium* and *E. moschatum*) seeds were introduced in California hay, and has become established on upland pastures on Hawaii and Molokai.

White clover (*Trifolium repens*) is found on Haleakala and Makawao pastures, Maui.

CROP PLANTS.

Sisal (*Agave sisalana*).

Various species of cucurbits (melons, squashes, pumpkins, cucumbers, etc.).

FORAGE PLANTS.

Alfalfa, several varieties.

Lupine, blue and yellow, is occasionally used as green-manure plant on sugar plantations.

Tangier pea (*Lathyrus tingitanus*) is growing at Haiku, Maui.

Sanfoin (*Onobrychis sativa*) is a forage plant introduced by Jared G. Smith in 1904. The seed was distributed to ranches.

ORNAMENTAL PLANTS.

Palms, particularly the royal and cocoanut.

Poppy, a horticultural form of *Romneya coulteri* is found in gardens in Honolulu.

Chinese ink-berry (*Cestrum diurnum*), *Thevetia neriifolia* and vines (*Ipomoea* spp.).

WEEDS.

Lantana, two species.

California sages (*Salvia*) were introduced by Hawaiian Bee Keepers' Association in 1907, but are not as yet established. They are suitable for waste, arid lands, are the most important honey plant in California and are also valuable as forage plants.

Ilima (*Sida* spp.), oi (*Verbena bonariensis*), pili grass (*Heteropogon contortus*), Spanish needle or lauki (*Bidens pilosa*), puakala (*Argemone mexicana*), alii (*Dodonaea viscosa spathulata*), and hila hila (undetermined). Other weeds are *Waltheria americana, Ipomoea pes-caprae* (vine along seacoasts), and *Malvastrum tricuspidatum.*

INSECT HONEYDEW.

The most important source of honey in the Hawaiian Islands, aside from the amount elaborated from the nectar of the flowers of algaroba, is honeydew derived from the secretion deposited on the leaves of sugar cane by the sugar cane leaf hopper (*Perkinsiella saccharicida*). Insect honeydew is derived, to a limited extent, also from the secretions of the sugar cane aphis (*Aphis sacchari*).

Further, in Hawaii, as in other tropical countries, plant lice, scale insects, and related families are abundant, and some insect honeydew is to be found on plants in almost any locality.

PLANT HONEYDEW.

While no great amount of this product is gathered and stored by honeybees in Hawaii, bees have been observed locally collecting the plant honeydew secreted by the extra floral nectaries on the leaves of hau trees (*Paritium tiliaceum*). The planting of cotton on a large scale will mean an increase in plant honeydew pasturage, since similar glands are found on the bracts of the bolls and the midrib of the leaves of the cotton plant.

A bulletin on Hawaiian Honey was published during the year. This bulletin is available for distribution and presents the character and source of the honeys of the islands in detail.

An event of great importance to the bee-keeping interests in Hawaii was an extended visit to the islands by Dr. E. F. Phillips, in charge of apiculture in the Bureau of Entomology. Dr. Phillips arrived in the latter part of February, 1908, and remained until April 1, visiting during this time all the principal apiaries on the islands of Oahu, Kauai, Molokai, Maui and Hawaii. The Hawaiian Bee Keepers' Association has taken an active part in the introduction of bee plants and in securing legislation pertaining to the importation and inspection of honeybees and honey.

PINEAPPLE INSECTS.

In 1904 the writer published a report on the pineapple scale (*Diaspis bromeliae*). With the great increase in the acreage devoted to pineapple culture, the mealy-bug (*Pseudococcus citri*) has become equally as serious as the scale if not more so. The scale is primarily leaf-feeding, while the mealy-bug infests the roots, the basal portions of the leaves, the center of the plant, and is particularly abundant at the base of the fruit. Aside from the injury to the plant, the mealy-bug injures the fruit directly by its feeding and indirectly by acting as an agent in the spread of the pineapple rot. The resulting injury blemishes the fruit, making it unfit for the fresh-fruit trade, and greatly impairs its keeping qualities during shipment.

Because of the large area of land now in pineapples it is important to control these species, both from the standpoint of increasing the production and from that of producing fresh fruit for shipment. The modern market will not accept inferior or infested fruit. The Hawaiian product is a superior fruit and the growers have undertaken vigorous measures to suppress insect pests.

During the last season it has been demonstrated that the scale and mealy-bug can be controlled in the field and that clean shipments of fruit are possible by proper methods of fumigation. It is sufficient to say that the fruit has passed inspection under the rigid horticultural quarantine law in operation at the port of San Francisco.

Trial fumigation of plants before setting them in the field indicates that plants will not stand as large a dosage of cyanid gas as fruit for shipment. In the case of fruit for shipment it is possible to use a dosage that will kill all forms of both the pineapple scale and the pineapple mealy-bug without injuring the fruit. Tests demonstrate that the plants are more susceptible to injury, and until the point of safety to which the dose can be increased is determined, the following dosage for the fumigation of plants is recommended: For every 100 cubic feet of air space use 1 ounce by weight of potassium cyanid, 2 fluid ounces of sulphuric acid, and 4 fluid ounces of water. The time required is one and one-half hours. A relatively smaller dose, with longer exposure, is less injurious than a larger dose and shorter exposure. Economy of labor can be obtained by increasing the capacity of the fumigation outfit in proportion to the length of time. With the above dose nearly all of the active forms are killed. The individuals developing from the immature forms must be treated later in the field.

For field treatment, an emulsion of kerosene is recommended for the scale, and tobacco dust for the mealy-bug. The kerosene emulsion is described in Press Bulletin No. 10. The tobacco-dust treatment consists in applying a small handful in the center of the plant, care being taken not to use the dust when the bud is forming or while the plant is in flower. Tobacco dust has been placed on the market in Honolulu for less than $45.00 per ton.

For fruit for shipment a larger dosage may be used, and 1½ ounces of potassium cyanid is recommended to every 100 cubic feet of air space, the proportion and time being the same as given for fumigating plants.

Fumigation work is being successfully done under canvas treated with oil or paint and in special air-tight rooms. The growers have the work well in hand and the insects affecting pineapples in Hawaii present no serious obstacles in the production and marketing of the fruit.

Acknowledgment is made of the helpful coöperation and suggestions of Mr. E. M. Ehrhorn, horticultural inspector at the port of San Francisco, in the work of determining the proper dosage for the fumigation of fruit for shipment.

MOSQUITOES.

The investigations relating to mosquitoes have been brought to a close. The important facts concerning the species of mosquitoes found in Hawaii, their breeding places and habits, and measures for their suppression, have been worked out and the information given to the public in bulletin form and in the reports of the station. The control of mosquitoes has been assumed by the Territorial Board of Health. The inspectors of the Board are doing very efficient work, in consideration of the fact that no funds for the work are available and consequently no addition to the force possible.

On August 3, 1906, regulations were adopted for mosquito prevention and abatement and made a part of the rules and regulations of the Board of Health of the Territory of Hawaii.

A REVISED LIST OF THE INJURIOUS INSECTS OF HAWAII.*

The list of injurious insects of Hawaii was begun in the report of the entomologist for the fiscal year 1904. The annual reports of the station have appeared in widely separated publications of the Department and some of the early reports are not now available. On this account and for the further reason that many additional determinations have been made and that some corrections are necessary it is deemed advisable to give herewith the complete list with references to the former reports. Additions to the list are given to bring the report down to date.

CROPS.

SUGAR.

The sugar-cane leafhopper (*Perkinsiella saccharicida*).[a]
The sugar-cane borer (*Sphenophorus obscurus*).[a]
The sugar-cane leaf-roller (*Omiodes accepta*).[a]
The sugar-cane mealy-bug (*Pseudococcus calceolariae*).[a]
The sugar-cane aphis (*Aphis sacchari*).[c]
Mole cricket (*Gryllotalpa africana*).[a]
Cockroach (*Eleutheroda dytiscoides*).[a]
Fuller's rose beetle (*Aramigus fulleri*).[a]
Longhorned grasshopper (*Xiphidium varipenne*).[c]

RICE.

The rice weevil (*Calandra oryza*).[c]
The Angoumois grain moth (*Sitotroga cerealella*).[d]
Mole cricket (*Gryllotalpa africana*).[c]
Longhorned grasshopper (*Xiphidium varipenne*).[c]
Shorthorned grasshopper (*Oxya velox*).[c]
The rust-red flour-beetle (*Tribolium ferrugineum*).[c]
The cadelle (*Tenebrioides mauritanica*).[c]
A beetle (*Rhizopertha pusilla*).[d]

COFFEE.

Scale insect (*Pulvinaria psidii*).[a]
Leafhopper (*Siphanta acuta*).[a]
Aphid (undetermined).[a]

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*The letters after the names in the list refer to former reports as follows:

[a] Ann. Rept. Hawaii Expt. Sta. 1904, U. S. Dept. Agr., Office Expt. Sta. Rpt. 1904, Washington, 1905, pp. 372-379.

[b] Report on Arigultural Investigations in Hawaii 1905., U. S. Dept. Agri. Office Exp. Stas. Bul. 170 Washington 1906, pp. 38-59.

[c] Ann. Rpt, Hawaii Exp. Sta. 1906, Washington, 1907, pp 18-32.

[d] Ann. Rpt. Hawaii Exp. Sta. 1907, Washington, 1908, pp. 25-51.

[e] Rpt. Governor Ter. of Hawaii, 1902, p. 35.

TARO.

Mole cricket (*Gryllotalpa africana*).[b]
Aphid (undetermined.)[b]

SISAL.

A weevil (*Pseudolus longulus*).[b]
Mealy-bug (*Pseudococcus* sp. undetermined).[b]
The black scale (*Saissetia oleae*).[b]

TOBACCO.

Tobacco leaf-miner (*Phthorimaea operculella*).[a]
Tobacco flea-beetle (*Epitrix parvula*).[a]
Tobacco hornworm (*Phlegethontius quinquemaculata*).[b]
Cigarette beetle (*Lasioderma serricorne*).[b]
Black cutworm (*Agrotis ypsilon*).[a]
Bollworm (*Heliothis obsoleta*).[a]
Japanese beetle (*Adoretus umbrosus tenuimaculatus*).

COTTON.

Bollworm (*Heliothis obsoleta*). This insect is the widely known bollworm of cotton of the southern United States. The writer observed its work on the young buds of tobacco in 1905, and in restricted areas its work was serious. It is periodically injurious to the ears of corn. The insect has not been observed on cotton nor is the species at all common. Since many of the food plants of the worm are common it would seem that the insect is held in check by some natural factor, probably tachinid flies. It is, however, an insect whose presence in the cotton fields it is well to anticipate.

Japanese beetle (*Adoretus umbrosus tenuimaculatus*). The Japanese beetle has been observed to skeletonize the leaves of the cotton plant in many of the plantings of cotton that have been made on a small scale in isolated places. The behavior of the beetle in fields of considerable area can not be predicted, but as it is a leaf feeder, its injury in the first place will not be as serious as that of forms attacking the boll; in the second place, it can be controlled by spraying with an arsenical poison. It is of interest to note that the Japanese beetle showed a decided preference for the Chinese variety of cotton—in comparison with the Caravonica—in the plantings made at the station during the year.

Small bollworm (*Gelechia gossypiella*). This species is noted by Dr. R. C. L. Perkins in 1902 as "Gelechiid (undetermined) attacking cotton bolls"[c] and recorded by Lord Walsingham under the above determination from Hawaii in Fauna Hawaiiensis[b] with the description and extended notes on the occurrence of the species in India and Japan. The moth was bred by the writer from infested cotton bolls received from Holualoa, Kona, Island of Hawaii, in 1905, and is common about Honolulu. A detailed study has been begun of the life-history of this moth and this with the feeding habits of the worm and possible means of suppression on a field basis will form the important part of the investigations to be undertaken by the assistant entomologist during the year.

A weevil (*Araeocerus fasciculatus*). This weevil was bred from cotton bolls received from Hookena, South Kona, Island of Hawaii, in December, 1905. Determined by Mr. E. A. Schwarz of the Bureau of Entomology.

Mealy-bug (*Pseudococcus filamentosus*). Very abundant at times on the young stems and bolls. Fed upon to a great extent by the ladybird beetle (*Cryptolaemus montrouzieri*).

Cotton aphis (*Aphis gossypii*). Determined by Mr. Th. Pergande of the Bureau of Entomology. Fed upon by larva of syrphus fly (*Xanthogramma grandicornis*) and predaceous plant-bug (*Zelus peregrinum*).

CASSAVA.

A snout-beetle (*Pseudolus longulus*).[b]
A longhorned beetle (*Lagocheirus araneiformis*).[b]

SWEET POTATO.

Sweet-potato weevil (*Cylas formicarius*).[d]
Sweet-potato sphinx (*Phlegethontius convolvuli*).[d]
Sweet-potato vine borer (*Omphisa anastomosalis*).[d]
A root maggot (*Pegomya fusciceps*).[d]

CORN.

Corn leaf hopper (*Dicranotropis maidis*).[a]

"Green fly" of corn (undetermined species of aphidid.)[a]

Cutworms (several undetermined species, among them *Agrotis ypsilon*).[a]

CABBAGE.

Cabbage aphis (undetermined, probably *Aphis brassicae*).[a] An internal parasite (*Lysiphlebus testaceipes*) has been bred from this aphis. It forms an important natural check to the aphis here.

A leaf-miner (*Plutella maculipennis*).[b] Parasitized by *Campoletis* (*Limneria*) *tibiator*.

Root maggot (*Pegomya fusciceps*).[d]
The cabbage butterfly (*Pontia rapae*).[a]
Cutworms (undetermined).[a]

MELONS.

The melon fly (*Dacus cucurbitae*)[a], illus. art.[d] It is believed that at the present price of melons it would pay to grow muskmelons at least, under cover, fertilizing the flowers by a colony of bees.

Aphidid (undetermined). Very abundant on young vines.

Stem borer (*Apomecyna pertigera*) larva of a Cerambycid. Taken in numbers from stems of watermelons at Makaha, island of Oahu. Determined by Mr. E. A. Schwarz of the Bureau of Entomology.

PINEAPPLE.

Pineapple scale (*Diaspis bromeliae*).[a]

Common mealy-bug (*Pseudococcus citri*).[d]

The pomace fly (*Drosophila ampelophila*).[d]

Red spider (*Stigmaeus floridanus*), Banks. Taken from pineapple on station grounds during the year.

CITRUS.

Purple scale (*Lepidosaphes beckii*).[a b]

Fluted scale (*Icerya purchasi*).[a]

Orange aphis (*Myzus citricidus*).[a c]

Scale (*Parlatoria ziziphus*).[d]

Leafhopper (*Siphanta acuta*).[a]

Common mealy-bug (*Pseudococcus citri*).[d]

Bark beetle (*Stephanoderes* sp.)[b]

Florida red scale (*Chrysomphalus aonidum*).[c]

Scale (*Pulvinaria psidii*).[c]

Mealy-bug (*Pseudococcus filamentosus*).[c]

Scale (*Coccus viridis*).[c]

Fuller's rose beetle (*Aramigus fulleri*). Injurious to limes on the island of Molokai during the summer of 1907.

Scale (*Coccus punctuliferus*). Collected from lime at Makaha, island of Oahu. Determined by Mr. Sanders of the Bureau of Entomology.

Cockroach (*Eleutheroda dytiscoides*). Determined by Mr. Caudell of the Bureau of Entomology. Received from Napoopoo, Kona, island of Hawaii. Reported as injurious to lime trees by girdling the branches.

MANGO.

The mango weevil (*Cryptorhynchus mangiferae*).[b]

Torpedo bug (*Siphanta acuta*).[a]

Scale (*Phenacaspis eugeniae*).[b]

The mango scale (*Coccus mangiferae*).[c]

Florida red scale (*Chrysomphalus anonidum*).[c]

Scale (*Trionymus americanus*).[d]

Thrips.[d] Mr. Th. Pergande of the Bureau of Entomology identified the thrips on the mango as *Heliothrips* sp, and says under date of March 3, 1908, that the species is apparently new.

Scale (*Pulvinaria mammeae*). Found also on orange, coffee and ferns. Originally described from Hawaii on the mammee apple (*Mammea americana*). Determined by Mr. J. G. Sanders of the Bureau of Entomology.

BANANA.

The sugar-cane borer (*Sphenophorus obcurus*).[a]
A borer (*Calandra remota*).[a]
The banana leaf-roller (*Omiodes meyricki*).[a] [d]
Florida red scale (*Chrysomphalus aonidum*).[b]
Scale (*Phenacaspis eugeniae*).[b]
Scale (*Saissetia nigra*).[c]

AVOCADO.

Avocado mealy-bug (*Pseudococcus nipae*).[a]
Scale (*Fiorinia fioriniae*).[a]
Scale (*Phenacaspis eugeniae*).[b]
Bark beetle (*Xyleborus immaturus*).[b]

FIG.

Avocado mealy bug (*Pseudococcus nipae*).[a]

Scale (*Saissetia nigra*). Taken from fig in Moanalua Gardens, Honolulu.

GRAPE.

Japanese beetle (*Adoretus umbrosus tenuimaculatus*).[a] [c]
Avocado mealy bug (*Pseudococcus nipae*).[a] [c]
Fuller's rose beetle (*Aramigus fulleri*).[c]
Mealy bug (*Pseudococcus filamentosus*).[c]
Larva of moth (*undetermined*).[c]

APPLE.

Japanese beetle (*Adoretus umbrosus tenuimaculatus*).[d]
Scale (*Pseudaonidia clavigera*).[d]

PEACH.

Fuller's rose beetle (*Aramigus fulleri*). Observed during the year in very destructive numbers on peach on the island of Molokai.

Peach scale (*Aulacaspis pentagona*).[a] Bark beetle, probably an undescribed species. Collected in Nuuanu Valley, Honolulu.

GUAVA.

Avocado mealy-bug (*Pseudococcus nipae*).[a]

Fuller's rose beetle (*Aramigus fulleri*). Feeding to great extent on guava on the islands of Hawaii and Molokai.

MULBERRY.

Avocado mealy-bug (*Pseudococcus nipae*).[c]
Mealy-bug (*Pseudococcus filamentosus*).[c]
Scale (*Saissetia* sp., undetermined).[c]

STRAWBERRY.

A ground beetle (*Ompatrum serratum*).[a]
Japanese beetle (*Adoretus umbrosus tenuimaculatus*. The Japanese beetle is the principal insect injurious to strawberries in Hawaii. The Japanese gardeners control the pest by picking.

SOUR-SOP.

Avocado mealy-bug (*Pseudococcus nipae*).[b]
Scale (*Coccus longulus*).[b]

COCOANUT.

Palm leaf-roller (*Omiodes blackburni*)[d].
Sugar-cane borer (*Sphenophorus obscurus*).[d]
Florida red scale (*Chrysomphalus aonidum*).[d]

ORNAMENTAL PLANTS.

HIBISCUS.

Mealy-bug (*Pseudococcus filamentosus*).[b]
Leaf caterpillar (*Cosmophila sabulifera*).[d]

ROSES.

Japanese beetle (*Adoretus umbrosus tenuimaculatus*).[a]
Rose aphis (*Macrosiphum rosae*).[d]
Rose scale ,*Aulacaspis rosae*).[a]
Fuller's rose beetle (*Aramigus fulleri*).[a]

PALMS.

Sugar-cane borer (*Sphenophorus obscurus*).[a]
Hemispherical scale (*Saissetia hemisphaerica*).[b]
Mealy-bug (*Pseudococcus pseudonipae*).[b]
Scale (*Chrysomphalus dictyospermi*).[b]
Florida red scale (*Chrysomphalus aonidum*).[c]

PEPPER TREE.

Scale (*Saissetia nigra*).[d]
Scale (*Aspidiotus lataniae*).[d]

BAMBOO.

Scale (*Asterolecanium miliaris*).[d]

CROTON.

Scale (*Lepidosaphes pallida*)[b].

IPOMOEA.

Scale (*Coccus hesperidum*). Parasitized by *Coccophagus immaculatus*).[b]

Sweet potato sphinx (*Phlegethontius convolouli* Linn). Collected from vines at the station.

OLEANDER.

Scale insect (*Phenacaspis eugeniae*).[c]

ASPARAGUS.

(*Asparagus sprengeri.*)

Avocado mealy-bug (*Pseudococcus nipae*). Collected during the year on the station grounds.

Scale (*Hemichionaspis minor*). Collected during the year on the station grounds. Determined by Mr. J. M. Sanders, of the Bureau of Entomology.

FOREST TREES

ALGAROBA.

(*Prosopis juliflora.*)

Longhorned beetles (*Cyllene crinicornis* and *Microcantha nutans*).[b]

Large powder beetle (*Bostrichus migrator*).[b]

Small powder beetle (*Sinoxylon conigerum*).[b]

The bean weevil (*Bruchus obtectus*).[b]

Scale insect (*Asterolecanium pustulans*).[d]

BLACK WATTLE.

(*Acacia decurrens.*)

Longhorned beetles (*Cyllene crinicornis, Xystrocera globosa, Ceresium simplex,* and *Sotenus setiger*).[b]

Weevil (*Bruchus* sp.).[b]

Wireworm (*Chalcolepidius erythroloma*).[b] Probably injurious to roots.

Barkbeetle (*Stephanoderes sp.*).[b]

Leafhopper (*Siphanta acuta*).[b]

Fluted scale (*Icerya purchasi*).[b]

Caterpillar of tineid moth (undetermined).[b] Beneath bark.

CEARA RUBBER.

Scale insects (*Saissetia nigra, Saissetia oleae,* and *Aspidiotus cyanophylli*).[c] [d]

Mealy-bug (*Pseudococcus* sp., undetermined).[c]

Barkbeetle (*Xyleborus affinis*).[d]

Snout-beetle (*Pseudolus longulus*).[d]

Wireworm (undetermined Elaterid).[d]

OHIA LEHUA.

(*Metrosideros polymorpha.*)

Fuller's rose beetle (*Aramigus fulleri*). This beetle is a very serious enemy of Ohia in certain districts on the island of Hawaii. Trees were observed in the Kohala mountains that were completely defoliated.

Termite (*Calotermes castaneus*). Taken from living trees in the Kohala mountains, island of Hawaii.

WILD GUAVA.

Barkbeetle (*Xyleborus affinis*).[d]
Scale insect (*Aspidiotus lataniae*).[d]

CATTLE.

Hornfly (*Haematobia serrata*).[a] [d]
Warble flies (*Hypoderma bovis* and *H. lineata*).[d]

SHEEP.

Sheep-maggot fly (*Calliphora dux*).[d]
Bluebottle flies (*Lucilia sericata* and *L. caesar*).[d]
Flesh flies (*Sarcophaga barbata* and *S. pallinervis*).[d]

Sheep head-maggot fly (*Oestrus ovis*).[d] This sheep head-maggot was taken from the head of a lamb on Molokai during the year and adult flies reared from the larvae. As previously stated, the species is recorded by Grimshaw from the island of Kauai in 1901. Its presence on the island of Molokai indicates that this persistent pest to sheep is established in the islands.

Horn fly (*Haematobia serrata*).[d]

HORSES.

Stable fly (*Stomoxys calcitrans*).[d]
Horse botflies (*Gastrophilus equi* and *G. nasalis*).[d]
"Night" mosquito (*Culex cubensis*).[d]

POULTRY.

The turkey louse (*Goniodes stylifer*). Collected on the island of Molokai during the year.

The chicken louse (undetermined).[d]
The chicken mite (undetermined).[d]
The "night" mosquito (*Culex cubensis*).[d]

HOGS.

The hog louse (*Haematopinus urius*). Received from Kamehameha School, Honolulu, during the year. Collected by F. G. Krauss.

DOGS.

The dog flea (*Ctenocephalus canis*).[d]

The dog tick (*Rhipicephalus sanguineus*).[d]

The "night" mosquito (*Culex cubensis*).[d] The mosquitoes—and especially the "night" mosquito—annoy all domestic animals, this annoyance being particularly noticeable in the case of horses, young poultry and dogs. It is believed, further, that this species is the transmitting agent of the disease of dogs known as "heartworm."

HOUSEHOLD INSECTS.

Mosquitoes (*Culex cubensis, Stegomyia calopus* (yellow fever mosquito), and *S. scutellaris*).[a]

Cockroaches (*Periplaneta americana* and *P. australasiae*).[a]

The typhoid or house fly (*Musca domestica*).[a]

Ants. Several species, undetermined, among them the cosmopolitan red ant.

Termite (*Calotermes marginipennis*).[a]

Bedbug (*Cimex lectularius*).

The dog flea (*Ctenocephalus canis*). (See under Live Stock).

Silverfish (*Lepisma* sp., undetermined).[a]

Carpenter bee (*Xylocopa aeneipennis*).[a]

Mud dauber (*Pelopoeus cementarius*).[a]

Clothes moth, undetermined.[a]

STORED PRODUCTS.

Rice weevil, (*Calandra oryza*).[a]

Cigarette beetle (*Lasioderma serricorne*).[a] [b]

Bean weevil (*Bruchus obtectus*).[a]

Rust-red flour beetle (*Tribolium ferrugineum*).[a]

Angoumois grain moth (*Sitotroga cerealella*). Common in stored rice.

Ham and cheese maggot (*Piophila casei*).[d]

Cadelle (*Tenebrioides mauritanica*).[d]

Weevil (*Calandra linearis*).[d]

Bamboo beetle (*Dinoderus minutus*).[a]

Bone-meal beetle (*Dermestes cadaverinus*).[b]

Beetles (*Silvanus mercator* and *Araeocerus fasciculatus*).[d]

Beetle (*Lophocateres pusilla*). Bred from rolled barley during the year.

Book louse (*Troctes divinatorius*). Common pest of dried specimens in museum collections, books, and taken during the year from rice flour.

ACCESSIONS TO ENTOMOLOGICAL LIBRARY RELATING TO HAWAIIAN ENTOMOLOGY.

(Continued from Report of the Entomologist, Annual Report of the Hawaii Agricultural Experiment Station for 1907, pp. 48-51.)

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REPORT OF THE HORTICULTURIST.

By J. Edgar Higgins.

SHIPPING TROPICAL FRUITS.

The chief work of the year in horticulture was in fruit shipping investigations. The fruits dealt with were pineapple, avocado, papaya, and banana, all of these being shipped to San Francisco. It was demonstrated that pineapples and avocados can be safely shipped as far as Chicago in refrigeration. This experimental shipment of a single carload was followed by two commercial shipments on the part of pineapple growers during the summer of 1908. A carload was sent to Denver and another to Chicago. The results of the experiments of the year 1907 were published in Press Bulletin 21 of the station and details need not be entered into in this report.

THE ORCHARDS.

TILLAGE AND IRRIGATION.

By a rearrangement of water pipes in the orchards tillage and irrigation have been facilitated. These pipes have been laid parallel to the rows of trees, so as not to interfere with tillage. Where possible, irrigation is practiced by the furrow system. A disk harrow is in frequent use and has been found a most efficient implement for maintaining the proper condition in the surface soil. The orchards are now in a more flourishing condition than at any time since they were planted.

COVER CROPS.

In an orchard of tropical fruits cover crops are not less important than in orchard work under temperate zone conditions. In some respects the need here is greater. The rapidity of oxidation of humus necessitates a frequent renewal, and an abundant supply is the more necessary since evaporation proceeds so rapidly. The torrential rains of the wet season render cover crops essential on steep grades to prevent the washing away of the soil. To these benefits will be added a gain in nitrogen if legumes are used.

The best time for sowing a cover crop is at the close of the dry season, as soon as there is sufficient mosture to give the crop a good start. In the months following there will be enough water to supply the needs of the trees and also the cover crop.

The latter may be plowed under just before the close of the wet season. If deep plowing is done after all rains are over, it will result in the loss of much moisture which might have been conserved.

There is one factor in the use of cover crops in the tropics which does not exist in temperate zone conditions. In temperate climates, most trees are dormant in winter, whereas in the tropics the rainy season brings growth even though it come during the coolest portion of the year. For this reason it may be well not to allow the cover crops to come too close to the trees. In the trials which have been made at this station the plants have not been permitted nearer than 5 feet from the trees. This space has been tilled with cultivators.

Many problems connected with the use of cover crops in Hawaii will have to be worked out under local conditions. The station has tested three promising legumes during the year. These were the cowpea (*Vigna catjang*), pigeon pea (*Cajanus indicus*), and jack bean (*Canavalia ensiformis*). Analyses have been made of these, as will be observed by reference to the Report of the assistant chemist.

The cowpea has made the quickest and most luxuriant growth, rapidly covering the ground and reaching maturity much earlier than any of the others. This plant is also recognized as having excellent feeding value either as hay or in the green form. If fed to stock and if the manure is properly cared for, and returned to the land, it is estimated that about 75 per cent of the nitrogen in the crop will be saved. One objection to the cowpea is its susceptibility to the attacks of aphis. These insects did no serious injury to the past year's crop, but at times have been very destructive.

The pigeon pea requires a much longer time to come to maturity. It makes an upright and spreading growth and is difficult to plow under when it has become full grown. If planted far enough apart to develop fully, the pigeon pea becomes too woody for a cover crop. If planted closely, the falling of the dead leaves makes a complete covering for the soil. The leaves of this plant are said to be useful as fodder. The seeds when nearly full grown may be used as a vegetable like green peas, which they closely resemble. The ripened seeds are also much used in the Tropics. The plant appears to be free from serious insect attacks. The jack bean is a plant of lower growth and although it is less rambling than the cowpea, it makes a good cover. It is quite free from insects.

ORCHARD INSECTS.

The chief insects which have required control on the orchard trees have been scales, mealy bugs and aphis. Kerosene emulsion, in the proportion of 1 part of stock solution to 14 parts of water, was used at the suggestion of the entomologist. This has been found to hold the insects in check and has caused no leaf injury, although used under all conditions of weather.

Another means of reducing the injury due to mealy bugs and aphis has been to apply a tanglefoot mixture to the trunks of the trees, thus arresting the passage of ants.

THE CITRUS ORCHARD.

In December, 1906, a small orchard of seedling citrus trees was planted. The first experinmental use of this is to make a test of the adaptability of different stocks, including rough lemon, shaddock (from Hawaiian grown seed), sweet orange, and the pomelo (from California seed). The soil is rather a light loam on a hill slope which is well drained at all times and in summer tends to be dry. In vigor of growth the different species have stood in the order named above. The rough lemon made a very strong growth, far excelling all the other stocks. This of course is only one feature of its character as a stock upon which to bud improved varieties of citrus. The budding of these stocks has begun, the method of trial being to put in each variety in a single tree of every row, thus making the row of a variety run at right angels to the rows of stocks.

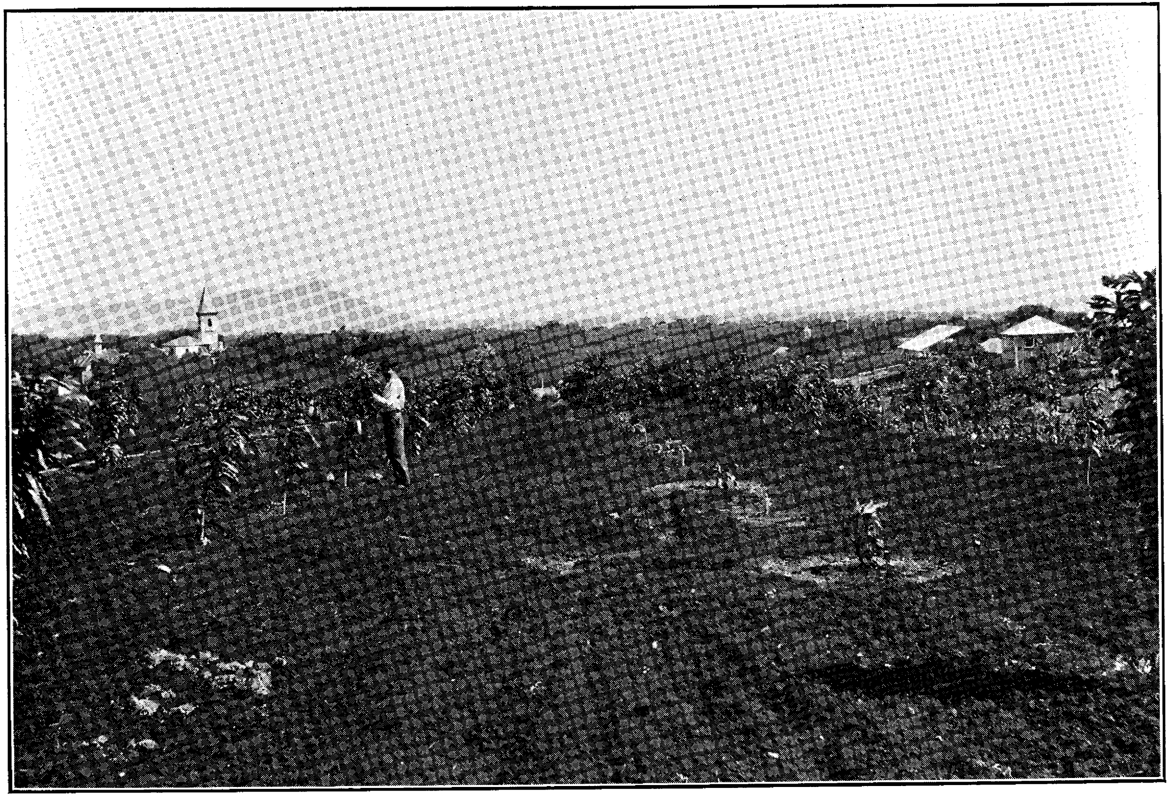
BANANAS.

The varieties of bananas which have occupied a part of the land near the laboratories were moved in March to the bottom of a gulch at a higher elevation. This change was made for several reasons. The bananas were occupying too much of the land near the laboratories that was needed for experiments requiring closer observation. The locality was also unfavorable for bananas, being unprotected from the wind. In the new location there is a greater rainfall, and protection from wind is afforded by the adjoining forest.

The requests for offsets, particularly of the Hawaiian varieties, have been so numerous that the stock has been constantly reduced and the most successful fruiting has been prevented. To avoid a repetition of this and to have offsets available, a banana nursery has been planted from which the different varieties can be drawn at times when the removal of offsets from the fruiting plants would be injurious. This nursery consists of large and well fertilized trenches in which offsets are planted closer than would be desirable for fruiting plants.

The following list of forty-three names includes the varieties of bananas now growing on the station lands: Chamaluco, Guaran or Gigante, Colorado or Marado, Colorado Blanco or Marado Blanco, Congo, Enano, Manzano, Platano Harton, Hua Moa, Lahi, Puhi, Ekiula, Moa, Platano Enano, Enano Doble, Datyl or Rosa, Cinerea, Congo Colorado or Congo Marado, Dominico, Pisang Sereh, Gruindy, Pisang Palembang, Pisang

PLATE II.



GENERAL VIEW OF MANGO AND AVOCADO ORCHARD.

Mango trees in foreground, Avocados beyond. The mango trees in the centre row which have been cut off have been budded.

Kelat, Apple, Hamakua, Malai-ula, Pisang Mass, Johnson (Santa Domingo) Macho, The Tunis, Manai-ula, Paapu, Ice Cream, Hua Alua, Red Cuban, Brazilian, Largo, Bluefields, Cavendishii from the Canary Islands, Chinese, Custard, Eleele, Lele.

It is probable that a few of the above names are synonyms. We are indebted to the Porto Rico Experiment Station for many of the introduced varieties. The Hawaiian varieties have been collected from different parts of the Territory, through the courtesy of numerous friends of the station. Many of these native varieties are quite out of their natural element on the Island of Oahu and none attain their greatest perfection here. Greater humidity of soil and atmosphere and the freedom from winds afforded by their native haunts render their growth and fruiting more luxuriant.

MANGOES.

BUDDING.

Experiments have been made in the budding of mangoes, with some failures and some very gratifying results. In the case of the variety Alphonse, 80 per cent of the buds have grown. The accompanying illustration shows the growth made from one of the buds 7½ months after it was set and 5 months after growth commenced. (See Pl. III, fig. 1.)

It is interesting to note that a period of over 2 months elapsed between the setting of the bud and its starting into growth, and that this was in early spring when vegetation is active. It is a commonly observed fact that the mango tree makes a sudden new growth, and increases the length of its branches several inches in a few days. It then ceases to grow for several weeks. matures its new wood, and prepares a terminal bud for another sudden increase. The budding must be done in the early part of one of these periods of growth. The bud must then await the next growing period before it can start, as would be the case with summer-budded deciduous fruit trees in the Temperate Zone.

The budding was done on seedling trees about 2½ years old. The method used was that of patch-budding.[a] The buds were set a few inches above the ground and when it appeared probable that a union had been effected between bud and stock the latter was cut through about four-fifths of its diameter, the top being allowed to rest on the ground. After the bud had begun to make new growth the top was completely removed.

Where failures occurred, the result of these trials points to an improper condition of bud wood at the time of the operation as the probable cause. While it is important in all budding that the stock should be in active growth so that the bark will separate readily from the wood along the line where new cells are being formed, this is even more important in the mango, where a large-sized piece of bark must be removed, leaving an unbroken surface to receive the new bud. With the mango, activity in the bud-wood is as important as in the stock. It is, therefore, necessary to watch the trees from which buds are to be taken and secure bud-wood at just the right period. This appears to be in the earliest stage of rapid growth and continues for only a few days. At this time they should be taken to the orchard and should be set in such trees as are in similar condition. A large majority of the trees will be found to be making a rapid growth at about the same time.

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[a] See Hawaii Sta. Bul. 12.

The quality of the bark in varieties appears to differ, some being quite brittle and corky. It may be that patch budding will not prove equally well adapted to all sorts of mangoes.

TRANSPLANTING.

The success with which the transplanting of a mango tree two or more years old can be performed bears an important relation to the methods to be pursued in propagation, and if budding is practiced the degree of success in moving will determine whether the budding must be done on trees in their permanent position in the orchard or may be practiced in nursery row as is done with citrus and deciduous fruit trees.

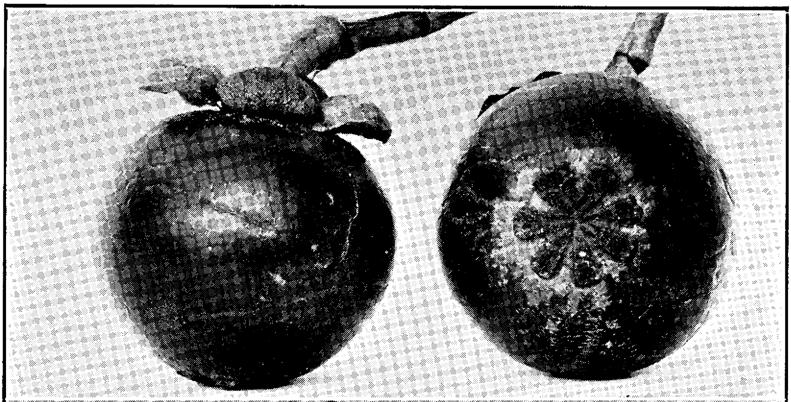
A few trials were made during the year in the moving of trees about 2½ years old. The test was severe in that it was made during the season of most active growth. All the trees were severely cut back, only the main stem remaining, and of this not more than 18 inches and usually only 6 inches. Some trees were lifted with naked roots and others were balled. None were for a long time out of the ground, and in this respect the test could have been more severe. The results have been quite satisfactory. None of the trees have died and most of them have made a good growth. No difference has been observed between the trees planted with balled roots and those with no soil surrounding them. The trees that were most severely cut back have made the most vigorous growth. While these experiments were not on a sufficiently large scale to justify positive conclusions, their indications are favorable to the handling of the mango as a nursery tree. However, even though this may be quite possible, budding in the orchard may still be more satisfactory.

INARCHING.

Inarching, or grafting by approach, has been practiced to a limited degree. This old and well established method is probably the surest means of propagating fine varieties of mangoes. It is, however, somewhat cumbersome and on a large scale would be expensive.

PLATE III.

Fig. 2. Mangosteen, (*Garcinia Mangostana.*)



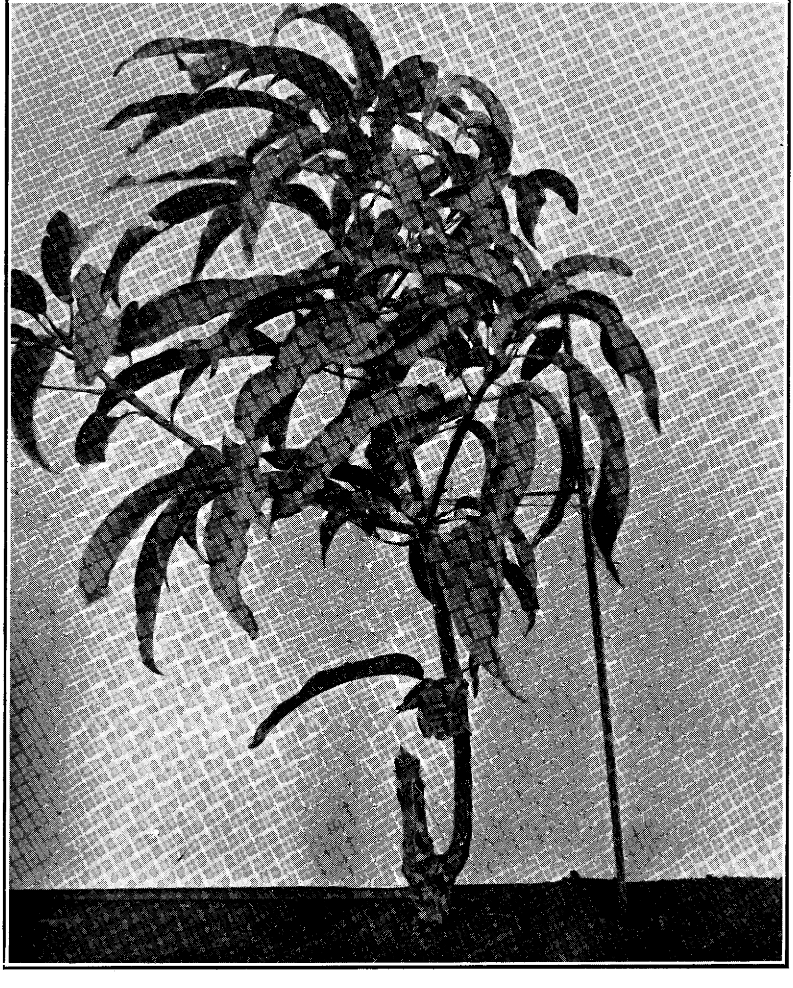


Fig. 1. A budded mango tree 7 1-2 months after the setting of the bud.

SHIPPING BY MAIL.

Shipping young trees by mail has been tried in coöperation with the Office of Seed and Plant Introduction, Bureau of Plant Industry. At different times during the year quite a number of young grafted trees were sent by mail from Washington, D. C., to Honolulu. These were very carefully packed and so far as the moisture of the roots on arrival was concerned, the condition was perfect. The losses, however, were many, due to the withering and dying of immature wood. In most instances also the trees became defoliated in transit or immediately after arrival. The indications were that only trees with firm wood and a dormant terminal bud should be shipped by this method. With such, a good degree of success may be expected.

FLOWERING SEASON.

The season of flowering of the mango in Honolulu has been noted with interest for several years. A record has been kept of the first flowers observed which appeared to be the beginning of a general blooming season, disregarding the few flowers that may appear at almost any time. The record of the beginning of the season has been as follows: January 1 to 10, 1906; December 10 to 12, 1906; November 15 to 20, 1907; and February 15 to 25, 1908. Attention is called to the fact that for three successive years each season of flowering has been nearly one month earlier than in the preceding year. For the mango crop of the summer of 1908 there were two seasons of quite general blooming among the mango trees of Honolulu, the first being in November and the second in February. It will be observed that a period of three months is thus covered which is in marked contrast to the seasons of flowering where climatic conditions are more sharply defined. It will be interesting and instructive to observe the continuation of this cycle.

BORDEAUX MIXTURE FOR BLIGHT.

The use of Bordeaux mixture in the control of mango blight (*Colletotrichum* sp.) has been reported in Bulletin 12, and elsewhere. During the past year some tests were made by Mr. C. J. Hunn, assistant horticulturist and gardener, to determine what strength of the mixture could be used with safety. The following formulas were used:

Formulas for Bordeaux Mixture.

6 lbs. copper sulphate, 6 lbs. lime, and 50 gals. water.
6 lbs. copper sulphate, 5 lbs. lime, and 50 gals. water.
6 lbs. copper sulphate, 4 lbs. lime, and 50 gals. water.
5 lbs. copper sulphate, 5 lbs. lime, and 50 gals. water.

In the case of the third formula considerable leaf injury was observed, and the second was not as satisfactory as the first, more than 5 pounds of lime being necessary to prevent injury from free copper.

PLANT ACQUISITIONS.

Something over 300 numbers have been added to the list of plant acquisitions during the year. Among the more important of these, the following may be mentioned:

"Henequen" (*Agava rigida elongata*). From Missouri Botanic Gardens, through Professor L. H. Dewey, in charge of Fiber Investigations, U. S. Department of Agriculture. The sisal fiber of commerce is derived from plants of the botanical varieties of *Agava rigida.* The present variety is the form commonly cultivated in Yucatan and is said to yield more heavily than the variety *sisalana* but the fiber is of a lower grade. A number of these were distributed and about 400 were planted in nursery row at the station. At first growth was slow, but recently they appear to have become well established.

The parties to whom the distributions were made report that growth has not been nearly so rapid as in the case of the variety *sisalana* under the same conditions. It is however, too early to judge of the merits of the plant as a source of fiber.

PINEAPPLES.

Seven varieties of pineapples of the product of artificial crosses, were received from the Subtropical Laboratory and Garden of the U. S. Department of Agriculture situated at Miami, Florida. The varieties have been described in the 1905 and 1906 Yearbooks of the Department of Agriculture. Those received are as follows: Miami, Deliciosa, Eden, Matthams, Dade, Coquina, and Jensen. Of these, in point of vigor the Eden has ranked first and the Dade second at this station.

ACHOCHA.

Seeds of this Bolivian vegetable were received from Mr. E. M. Ehrhorn, deputy commissioner of horticulture for the State of California. The plants grew vigorously and flowered profusely, but soon after the flowering began, they were completely destroyed by the melon fly.

Sweet sop (*Anona squamosa*), received from Mr. Harry Roberts, Honolulu.

Barleria flava, a yellow flowered ornamental shrub grown from seeds received from the Bureau of Agriculture, Manila.

Sapodilla (*Achras sapota*).

Wampi fruit (*Clausena wampi*). This much esteemed fruit of China and India has been growing in Hawaii in a few gardens for many years, but has never been in general cultivation. The tree is 10 feet to 15 feet in height and produces fruits about $\frac{3}{4}$ to $\frac{7}{8}$ inch in length, and about $\frac{1}{2}$ inch in diameter. It has a straw yellow color and pleasant flavor.

Feijoa sellowiana, a fruit about 2½ inches long and 2 inches thick, with white pulpy flesh said to resemble the guava and the pineapple in flavor. Received from the Couthern California Acclimatization Association.

The cherimoya (*Anona cherimolia*). This highly prized fruit flourishes in a half wild condition in some parts of Hawaii. Quite a large number of seedlings have been grown in the propagating houses for trial at different altitudes on the station tract.

The litchi (*Nephelium litchi*). Two introductions of this species have been made during the year, in each case through the Office of Seed and Plant Introduction. These included three or more of the best Chinese varieties and should make a very valuable acquisition to Hawaiian grown fruits.

Camphor (*Camphora officinalis*). A large number of plants have been grown from seeds received from the Yokohama Nursery Company.

The roselle, variety Victor (*Hibiscus sabdariffa*). A new variety received from the Subtropical Laboratory and Garden, Miami, Florida.

The mangosteen (*Garcinia mangostana*). Pl. III, fig. 2). Two fruits were obtained, in one of which there was a single fertile seed. This has germinated and the seedling is doing well.

The papaya (*Carica papaya*). Four varieties received from Government Stock Gardens, Ceylon.

PLANTS DISTRIBUTED.

The station has continued the practice of distributing seeds and plants of species considered to be worthy of a much more general cultivation and which are not readily obtainable from nurserymen and seedsmen. Among these have been roselle (*Hibiscus sabdariffa*), Bluefields banana, star apple (*Chrysophyllum cainito*) carambola (*Averrhoa carambola*), and many others. At the request of the entomologist, nearly 2,000 mulberry cuttings have been sent to those who are interested in silk production. A record is being kept of all distributions and recipients are expected to report upon the condition of plants entrusted to their care.

MISCELLANEOUS.

Much needed assistance in horticultural work has been provided by the appointment of Mr. Chester J. Hunn to the position of assistant horticulturist and gardener. Mr. Hunn arrived in Honolulu in February, 1908, and began work at once.

The deciduous plantings at the Parker ranch on Hawaii, which were referred to in the last annual report, were visited in March, 1908. At this time all trees requiring it were pruned. The apple and peach trees had made a remarkably vigorous growth at 4,000 feet altitude, and some varieties of peaches were heavily set with fruit buds. The pears, cherries, and apricots had not done so well. At the other orchards the apples and peaches had grown satisfactorily, but not so rapidly as at Waiki, which is at 4,000 to 5,000 feet altitude. The differences, however, appear to be due to other causes than altitude. The soil, situation, and climate at Waiki seem particularly well adapted to the growth of apple and peach trees. It is too early yet to speak of their fruiting and the relation of the flowering season to late frosts.

The greatest hindrances are insects, chief among these being climbing cutworms and Fuller's rose beetle, locally known as "Olinda bug." As a result of these insect attacks a large percentage of the dormant buds was destroyed and the bark from the end of the twigs was eaten. In some instances fully three-quarters of the season's growth was completely stripped. Tree Tanglefoot has since been tried as a means of preventing these injuries, but no reports of its efficiency have yet been received.

The station again coöperated with the Hawaiian Poultry Association in preparing an exhibit of agricultural and horticultural products. The winter season, which is best for a show of poultry, is quite unfavorable for a horticultural exhibition. Nevertheless, a considerable number of interesting things were brought in by the exhibitors.

Some interest has been manifested in the growing of red peppers and an effort has been made to ascertain the probable market for these in the dried form. The wholesale price of these in New York ranges from 7½ to 15 cents per pound. The exact consumption has not yet been ascertained, but it is stated by one company that its annual purchases of cayenne pods amount to several hundreds of tons.

The Waialee Industrial School has grown Tabasco peppers on a small scale. The principal, Mr. T. H. Gibson, estimates that the cost of picking would be about 1 cent per pound. It is too early yet to have any accurate data as to the yields, but it would appear that this is a promising crop. It is certainly a crop that can be marketed at long distances. Several large dealers have requested that a sample of sufficient size for testing be shipped to them.

REPORT OF THE ASSISTANT CHEMIST.

By Alice R. Thompson.

CHEMICAL STUDIES OF RICE AND RICE PRODUCTS.

The principal work of the last year has been that of determining the composition of paddy, straw, and rice grain. Mr. F. G. Krauss, of this station, obtained the samples from rice grown under his direction and from rice imported from Japan for comparison. The question of the food value of rice grown in Japan is rather an important one, the Japanese claiming their rice to be of superior quality as regards richness, hence the preference shown by Japanese to the imported rice.

The samples analyzed were of three kinds of rice—one, the imported Japan rice, another the Hawaiian grown rice of the Japan variety, and the third, Hawaiian Gold Seed rice grown in Hawaii.

Each kind of rice was divided into two samples, one of rice thoroughly polished; the other, of rice still "in the brown."

The analyses of the rices are as follows:

Composition of different kinds of rice.

[Air-dry material.]

Variety	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.
Polished.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Imported Japan	13.72	6.39	0.64	76.76	1.81	0.68
Station-grown Japan	13.05	6.47	.71	76.66	2.24	.87
Hawaiian (Gold Seed)	14.10	6.78	.46	76.86	1.32	.48
In Brown						
Imported Japan	13.40	7.09	2.08	73.87	2.22	1.34
Station-grown Japan	13.02	6.79	2.10	74.09	2.35	1.65
Hawaiian (Gold Seed)	13.79	7.14	2.13	72.87	2.74	1.33

Composition of different kinds of rice.

[Dry-matter basis.]

Variety.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.
Polished.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Imported Japan	7.40	0.74	88.97	2.10	0.79
Station-grown Japan	7.44	.82	88.16	2.58	1.00
Hawaiian (Gold Seed)	7.89	.54	89.47	1.54	.56
In Brown.					
Imported Japan	8.18	2.40	85.31	2.56	1.55
Station-grown Japan	7.81	2.41	85.18	2.70	1.90
Hawaiian (Gold Seed)	8.28	2.47	84.53	3.18	1.54

As may be noticed, there is no very great difference in the chemical composition of the rices. Especially is this true where the polished rices are compared separately with the unpolished. It was to be expected, since the bran of rice is high in fat and protein, that the unpolished rice should have a higher fat and protein content than the polished. Comparing the rices, it is noticeable that the unpolished rice has from three to four times as much fat as the polished, and the protein content is from 0.8 to 0.4 per cent higher in the unpolished. The ash and fiber are also higher in the unpolished.

But as far as the varieties are concerned there is but little increase of food value in the Japan imported rice as compared with the Hawaiian grown rice, Japan or Hawaiian standard seed. In the polished condition there is about 0.4 per cent more fat in the Japan variety, but about 0.5 per cent more protein in the Hawaiian variety (comparing the results as set forth in the "water-free material" table). In the unpolished condition the protein and fat contents of the three samples are almost identical.

The nitrogenous constituents of the rices are shown in the following table:

Nitrogenous constituents of rice.

[Fresh material.]

Variety.	Total Nitrogen.	Proteid nitrogen.	Amid nitrogen.	Crude protein (total N x 6.25)	True protein (proteid N x 6.25)	Amids calculated as asparagin.
Polished.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Imported Japan	1.022	1.022	....	6.39	6.39	....
Station-grown Japan	1.035	1.035	....	6.47	6.47	....
Hawaiian (Gold Seed)	1.085	1.085	....	6.78	6.78	....
In Brown.						
Imported Japan	1.134	1.126	0.008	7.09	7.04	0.04
Station-grown Japan	1.087	1.081	.006	6.79	6.76	.03
Hawaiian (Gold Seed)	1.142	1.142	....	7.14	7.14	....

It will be seen that there is little or no difference between the total nitrogen and albuminoid nitrogen.

During the ensuing year, analyses will be made of other rices, but the work already indicates that the claim for the superiority of Japan imported rice over Hawaiian-grown rice will not hold so far as the nutritive value of the rices is concerned.

Analysis of rice paddy and straw of rices grown from seed of different varieties was made, also of rice of the same variety grown under different conditions. Samples were taken and dried by Mr. F. G. Krauss and sent to this laboratory for analysis.

The Japan Seed rice paddy has the lowest protein value. The Japan Seed rice and the dry-land grown rice contain a little more fat than the Gold Seed, and about 4 per cent more fiber. Studying the ash constituents, the Japanese rice and the dry-land grown rice contain the highest percentage of potash,—the Japan the least phosphoric acid,—the Hawaiian rice the most lime. The magnesia is about the same all through.

In one case the dry-land rice variety was grown under wet-land conditions. Under these conditions the protein and fiber became less, the lime a little higher, but no other especial change was produced.

The composition of the rice straw is not so definite as that of the paddy. Rice of the same variety varies. From the following tables, however, it is seen that the dry-land rice grown under dry-land conditions has less fiber but higher protein content than the other rice.

Composition of rice hay (straw and paddy).

[Air-dry material].

Variety of rice.	Proximate constituents.						Ash constituents.				
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Soda.	Lime.	Phosphoric acid.	Magnesia.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Japan Seed, grown at Kailua	9.85	4.04	1.67	46.02	24.30	14.12	1.567	0.288	0.547	0.323	0.219
Japan Seed, grown at station trial grounds	9.11	4.03	1.69	45.40	23.80	15.97	1.381	.273	.296	.364	.202
No. 65 (dry-land grown)	10.26	6.38	1.96	42.40	23.30	15.70	1.370	1.40	.264	.693	....
No. 68 (dry-land grown)	10.28	6.29	1.60	49.28	18.84	13.71	1.082	1.20	.214	.726	....
Standard Hawaiian Gold Seed, grown at trial grounds	9.72	4.21	1.47	43.48	24.81	16.31	1.850	.276	.350	.320	.259
Standard Hawaiian, grown at Palama	9.86	3.45	1.66	43.00	27.74	14.29	1.614	.641	.349	.280	.160
No. 65 grown under wet-land conditions	9.64	3.76	1.65	47.08	25.31	12.56	1.228	.330	.386	.381	.188

Composition of rice hay.

[Dry-matter basis.]

Variety of rice.	Proximate constituents.					Ash constituents.				
	Protein.	Fat	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Soda.	Lime.	Phosphoric acid.	Magnesia.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Japan Seed, grown at Kailua	4.48	1.85	51.06	26.95	15.66	1.738	0.319	0.607	0.358	.0243
Japan Seed, grown at station trial grounds	4.43	1.86	51.96	26.18	15.57	1.519	.300	.326	.400	.222
No. 65 (dry-land grown)	7.09	2.18	47.28	25.96	17.49	1.526	1.560	.294	.772	....
No. 68 (dry-land grown)	6.97	1.78	54.99	20.99	15.27	1.205	1.337	.238	.809	....
Standard Hawaiian Gold Seed, grown at trial grounds	4.66	1.63	48.19	27.46	18.06	2.048	.306	.387	.354	.287
Standard Hawaiian, grown at Palama	3.83	1.84	47.72	30.76	15.85	1.790	.711	.387	.311	.177
No. 65 grown under wet-land conditions	4.16	1.82	52.14	27.99	13.89	1.358	.365	.427	.421	.208

Nitrogenous constituents of rice.

[Air-dry material.]

	Total nitrogen.	Proteid nitrogen.	Amid nitrogen.	Crude protein (total N x 6.25).	True protein (proteid N x 6.25).	Amids calculated as asparagin.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Paddy.						
Japan Seed (Kailua)	0.938	0 936	0.002	5.86	5.85	0.01
Japan Seed (trial grounds)	.990	.962	.028	6.19	6.01	.13
Dry-land No. 65	1.667	1.462	.205	10.42	9.14	.96
Dry-land No. 68	1.247	1.247	.000	7.79	7.79	.00
Standard Hawaiian (trial grounds)	1.382	1.381	.001	8.64	8.63	.01
Standard Hawaiian (Palama)	1.117	1.117	.00	6.98	6.98	.00
Dry-land No. 65 grown under wet-land conditions	1.094	1.094	.00	6.84	6.84	.00
Straw.						
Japan Seed (Kailua)	.400	....	....	2.50	....	....
Japan Seed (trial grounds)	.472	.403	.059	2.950	2.520	.32
Dry-land No. 65	.696	.585	.111	4.35	3.66	.52
Dry-land No. 68	.768	.744	.024	4.80	4.65	.11
Standard Hawaiian (trial grounds)	.438	.391	.047	2.74	2.44	.22
Standard Hawaiian (Palama)	.327	.289	.038	2.04	1.81	.18
Dry-land grown under wet-land conditions	.405	.364	.041	2.53	2.28	.19
Hay.						
Japan Seed (Kailua)	.646	....	....	4.04	....	....
Japan Seed (trial grounds)	.644	.589	.055	4.03	3.68	.26
Dry-land No. 65	1.019	.877	.142	6.37	5.48	.67
Dry-land No, 68	1.007	.995	.012	6.29	6.22	.06
Standard Hawaiian (trial grounds)	.674	.638	.036	4.21	3.99	.17
Standard Hawaiian (Palama)	.552	.525	.027	3.45	3.28	.13
No. 65 grown under wet-land conditions	.602	.572	.030	3.76	3.58	.14

Composition of paddy.

[Air-dry material.]

Variety of rice.	Proximate constituents.						Ash constituents.				
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Soda.	Lime.	Phosphoric acid.	Magnesia.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Japan Seed, grown at Kailua	12.01	5.86	1.97	63.32	10.86	5.98	0.511	0.069	0.080	0.577	0.206
Japan Seed, grown at station trial grounds	11.47	6.19	1.95	64.46	10.25	5.68	.503	.119	.090	.660	.235
No. 65 dry-land grown	11.54	10.42	2.19	59.36	10.84	5.65	.470	.114	.113	.740	....
No. 68, dry-land grown....................	11.30	7.79	1.77	61.52	10.30	7.32	.438	.125	.106	.785	....
Standard Hawaiian Gold Seed, grown at station trial grounds........	11.58	8.64	1.47	64.46	7.46	6.39	.370	.023	.140	.692	.211
Standard Hawaiian Gold Seed, grown at Palama..	11.78	6.98	1.64	66.30	7.66	5.64	.346	.095	.170	.698	.235
No. 65 grown under wet-land conditions, at Palama............	11.93	6.84	1.86	65.47	8.20	5.70	.449	.069	.170	.730	.246

Composition of paddy.

[Dry-matter basis.]

Variety of rice.	Proximate constituents.					Ash constituents.				
	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Soda.	Lime.	Phosphoric acid.	Magnesia.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Japan Seed, grown at Kailua	6.66	2.24	71.97	12.34	6.79	0.583	.078	.091	0.655	0.234
Japan Seed, grown at station trial grounds.....	6.99	2.20	72.83	11.57	6.41	.568	0.134	.102	.745	0.265
No. 65, dry-land grown ...	11.78	2.47	67.12	12.25	6.38	.531	0.129	.128	.836	....
No. 68, dry-land grown ...	8.78	1.99	69.37	11.61	8.25	.494	0.141	.119	.885	....
Standard Hawaiian Gold Seed, grown at station trial grounds.....	9.77	1.66	72.90	8.44	7.23	.418	.26	.158	.783	.239
Standard Hawaiian Gold Seed, grown at Palama	7.89	1.85	75.23	8.66	6.37	.391	.107	.192	.789	.266
No. 65, grown under wet-land conditions at Palama	7.76	2.11	74.35	9.31	6.47	.510	.078	.193	.829	.279

Composition of rice straw.

[Air-dry material]

Variety of rice.	Proximate constituents.						Ash constituents.				
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Soda.	Lime.	Phosphoric acid.	Magnesia.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Japan Seed, grown at Kailua	8.77	2.50	1.52	37.99	31.02	18.20	2.096	0.398	0.625	0.197	0.181
Japan Seed, grown at station trial grounds	8.25	2.95	1.57	35.51	30.59	21.13	1.821	.350	.400	.216	.185
No. 65, dry-land grown	9.62	4.36	1.84	33.92	29.53	20.73	1.820	.154	.340	.670	....
No. 68, dry-land grown	9.26	4.80	1.44	37.01	27.39	20.10	1.727	.115	.323	.667	....
Standard Hawaiian Gold Seed, grown at station trial grounds, (wet-land)	9.10	2.74	1.48	36.48	30.59	19.61	2.350	.361	.420	.197	.275
Standard Hawaiian Gold Seed, grown at Palama (wet-land)	9.09	2.04	1.67	33.68	35.77	17.75	2.121	.860	.420	.114	.130
No. 65, grown under wet-land conditions at Palama	8.72	2.53	1.56	37.44	32.16	17.59	1.540	.435	.473	.242	.166

Composition of rice straw.

[Dry-matter basis.]

Variety of rice.	Proximate constituents.					Ash constituents.				
	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Soda.	Lime.	Phosphoric acid.	Magnesia.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Japan Seed, grown at Kailua	2.74	1.67	41.64	34.00	19.95	2.297	0.436	0.685	0.216	0.198
Japan Seed, grown at station trial grounds	3.21	1.71	38.76	33.31	23.01	1.983	.381	.463	.235	.201
No. 65, dry-land grown	4.81	2.04	37.56	32.66	22.93	2.013	.170	.376	.741	....
No. 68, dry-land grown	5.29	1.59	40.79	30.18	22.15	1.903	.127	.356	.735	....
Standard Hawaiian Gold Seed, grown at station trial grounds, (wet-land)	3.01	1.63	40.14	33.65	21.57	2.585	.397	.462	.217	.303
Standard Hawaiian Gold Seed, grown at Palama (wet-land)	2.31	1.84	37.03	39.31	19.51	2.331	.945	.461	.125	.143
No. 65, grown under wet-land conditions at Palama	2.77	1.71	41.04	35.22	19.26	1.686	.476	.518	.265	.182

As for its ash constituents, the dry-land variety of straw takes up less lime but much more phosphoric acid than the other rices.

In case the dry-land variety is grown under wet-land conditions, the crude fiber and lime increase and the protein and phosphoric acid decrease. There is not much difference between the Japan wet-land rice and the Hawaiian wet-land rice.

The composition of rice hay is calculated from the analyses of both paddy and straw, knowing the proportion of paddy to straw. Only the dry-land rice hay is at present of practical importance as it can be most cheaply grown. As it has the highest protein content, it will be of more value as a fodder.

MISCELLANEOUS FODDERS.

Besides the analyses of several samples of rice hay as fodder, two samples of Rhodes grass, one of cassava waste, three of leguminous plants, and one of American wheat hay were analyzed.

The Rhodes grass, compared with the wheat hay, contains a higher percentage of protein, about the same amount of fat, fiber and ash, and about twice as much lime.

The legumes (tops analyzed) have an especially high protein content, the pigeon pea containing the most nitrogen. The fat content of the cowpea is lower than that of American cowpeas, but the jack bean and pigeon pea contain a good deal of fat (as estimated by ether extraction). The cowpea has a higher fiber content than the average pea grown in America.

The legumes were grown on the station grounds and the yields per acre, estimated by Mr. F. G. Krauss, are as follows: Cowpea, 17,000 to 22,000 pounds; pigeon pea, 8,100 to 11,000 pounds; jack bean, 11,000 to 15,000 pounds.

The analyses of the fodders are given in the following tables:

Composition of miscellaneous fodders.

	Proximate constituents.						Ash constituents.		
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Potash.	Lime.	Phosphoric acid.
Air-dried.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Rhodes grass hay	11.75	6.08	2.31	42.51	30.20	7.15	1.314	0.730	0.280
Rhodes grass hay	9.87	7.25	1.39	44 64	29.21	7.64	....	.805	....
Wheat hay	9.44	4.48	1.82	45.14	31.80	7.32	....	.375	....
Fresh material.									
Cow-pea (*Vigna catjang*)	83.15	3.71	.22	5.26	5.75	1.91	.681	.290	.183
Pigeon-pea (*Cajanus indicus*)	70.00	7.11	1.65	7.88	10.72	2.64	.904	.428	.259
Jack bean (*Canavalia ensiformis*	76.81	5.21	.48	8.44	6.36	2.70	.650	.780	.162

Composition of miscellaneous fodders.

[Dry-matter basis.]

	Proximate constituents.				Ash constituents.		
	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Potash.	Lime.	Phosphoric acid.
Rhodes grass ;	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Sample No. 1	6.88	2.62	48.19	34.21	1.49	0.83	0.32
Sample No. 2	8.07	1.54	49.53	32.39	....	.892	....
Cassava	1.36	.58	87.36	9.06	.32	.470	.117
Cow-pea (*Vigna catjang*)	21.99	1.33	31.20	34.15	4.04	1.72	1.087
Pigeon pea, (*Cajanus indicus*)	23.69	5.51	26.26	35.73	3.014	1.425	.862
Jack bean (*Canavalia ensiformis*)	22.44	2.08	36.42	27.42	2.801	3.365	.697
Wheat hay	4.95	2.01	49.84	35.12	....	.414	....

Nitrogenous constituents of miscellaneous fodders.

(Fresh material).

	Total Nitrogen.	Proteid Nitrogen.	Amid Nitrogen.	Crude protein (total N x 6.25).	True protein (proteid N x 6.25).	Amids calculated as asparagin.
Rhodes grass:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sample No. 1	.972	0.760	0.212	6.08	4.75	1.00
Sample No. 2	1.160	.956	.204	7.25	5.98	.96
Cassava	.190	.190	.....	1.19	1.19	......
Cowpea	.593	.424	.169	3.71	2.65	.80
(*Vigna catjang*).						
Pigeon pea	1.137	.998	.139	7.11	6.24	.65
(*Cajanus indicus.*).						
Jack bean	.833	.629	.204	5.21	3.93	.96
(*Canavalia ensiformis*).						
Wheat hay	.717	.611	.106	4.48	3.82	.50

FERTILIZER ANALYSES.

But five samples of materials intended for fertilizers have been analyzed as follows:

Analyses of Fertilizer Materials.

Fertilizer Materials.	Moisture.	Phosphoric Acid.	Potash.	Nitrogen.	Lime.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Castor pomace	10.72	1.818	1.310	5.190	1.02
Peanut meal	10.59	1.642	1.284	8.360	.46
Cowpea (*Vigna catjang*)	83.15	.101	.408	.526	.491
Pigeon pea (*Cajanus indicus*)	70.00	.202	.788	.783	.312
Jack bean (*Canavalia ensiformis*)	76.81	.218	.783	.723	.438

The castor pomace and peanut meal were imported from China. It is believed that neither the pomace nor the meal will ever come into general use in these islands, as commercial fertilizers are extensively used and apprecited; and the more inferior organic fertilizers cannot take their place.

The legumes (whole plant analyzed) have a high nitrogen content. The analyses of the cowpea grown at this station show a higher content of nitrogen, phosphoric acid, and potash than that found in cowpeas grown in America. The jack bean compares favorably with the cowpea in composition. The pigeon pea (a tropical plant) and the jack bean contain the most nitrogen. These legumes may be especially appropriate as fertilizers for Oahu coast soils, where the humus is deficient.

The yields per acre of legumes (roots included) raised at this station were as follows: Cowpea, 18,000 to 23,000 pounds; pigeon pea, 9,000 to 12,000 pounds, and jack bean, 15,000 to 19,000 pounds.

SOILS.

A number of samples of soils were analyzed during the year, as follows:

Analysis of samples of Hawaiian soils.

No. of sample	Moisture.	Organic matter and combined water.	Nitrogen.	Phosphoric acid.	Potash.	Lime.	Magnesia.	Manganese oxide.
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
1	14.141	....	0.505	0.185	0.178	0.59	1.622	0.115
2	15.263	....	.555	.277	.151	.69	2.204	.130
3	3.763	15.864	.295	.127	.547	.940	.450	.400
4	9.429	10.441	.193	.223	1.553	3.29	....	.120
5	....	....	.148	....	.254	.57	....	....
6	8.907	14.726	.328	.198	.248	2.280	1.672	.120
7	7.536	13.660	.226	.127	.148	1.720	1.564	.130

The two soils, Nos. 1 and 2, are pineapple soils obtained from a field near Hilo, Hawaii. No. 1 is a brown loam, acid in reaction, taken from the Hamakua end of the field; No. 2 is also a brown loam, acid to litmus, and taken from the Puna end. The lime content is low in both soils, which fact accounts for the acidity noticed. The potash is low also.

Soil No. 3 came from upper Hoaeae and is a dark red loam, neutral in reaction with litmus. It contains a great abundance of humus; the nitrogen and potash are high; the lime rather low for the kind of soil, and the phosphoric acid low for a Hawaiian soil. Pineapples are growing well on the land.

No. 4 comes from land near Diamond Head and is a brown clay loam, effervescing with acid, showing presence of calcium carbonate. The humus is very low, scarcely coloring the potash solution. Results indicate that the lime is high, the phosphoric acid and nitrogen fair, and the potash abnormally high (sample may be an abnormal one). A crop of legumes grown and turned under on the land would probably improve the land, as there is very little humus.

Another soil from land near Diamond Head was also examined and proved to contain no humus at all. A large amount of effervescence followed action of acid on the soil, showing presence of much calcium carbonate. This soil contained but 0.098 per cent nitrogen.

Soil No. 5 came from the Palama district of this island, and is a red clay loam, neutral to litmus. The soil is rather low in potash and lime.

One soil was obtained from Palolo Valley and lime advised for it, as it was found to be quite acid.

The nitrogen was determined in five rice soils of Oahu and is as follows: Kailua, 0.186 per cent; Palama, 0.328 per cent; Punaluu soils toward litmus was acid, that of the station trial trial grounds, 0.224 per cent. The reaction of the Kailua and Punaluu soils toward litmus was acid, that of the station trial grounds slightly acid, and that of the Palama and Waikiki soils neutral.

Soils Nos. 6 and 7 are rice soils, obtained from Palama and Punaluu, respectively. No. 6 is a brown clay loam, and the analysis indicates a small deficiency of potash, while the lime is high. No. 7 is a dark brown loam and is deficient in potash and phosphoric acid, but high in lime. In both soils the lime content is higher than the magnesia, which relation is often found reversed in Hawaiian soils.

WATER ANALYSES.

One sample of irrigation water from Hilo was analyzed and found to contain 78.27 grains of total solids, and 35.23 grains of salt per gallon. This explained the dying of young fruit trees irrigated with this water.

Fourteen samples of drainage water from a rice lysimeter experiment were analyzed for potash, phosphoric acid, magnesia, lime, and nitrogen. The results indicate that ammonium sulphate used as a fertilizer causes loss of lime in the soil. Addition of magnesium salts causes an increase of magnesia in the drainage water. Only traces of phosphoric acid were found in the sample of water.

MISCELLANEOUS WORK.

The wax left in slum gum from which wax had been extracted by a new method was determined. Only 25.27 per cent wax was found. The percentage of slum gum left on extraction was also very small.

A sample of koa bark sent from Hawaii contained 19.91 per cent tannin in the water-free material. A sample of ohia bark had but 5.73 per cent tannin in the water-free state. No further effort has been made by those interested in koa bark to obtain tannin.

A fertilizer experiment was carried out with rubber plants, using paraffin pots and fertilizers, according to the wire-basket method devised by the Bureau of Soils of the U. S. Department of Agriculture.[a]

The soil used was from station land. The idea was to study the effects of different fertilizers on the rubber plant of the Para variety in soil of station land type. The results are as follows:

(*Pot Experiments with fertilizers for Para rubber.*)

Fertilizer used.	Average transpiration.	Average weight of plant.
	Grams.	*Grams.*
Check	10.95	3.14
Phosphoric acid	11.56	3.42
Sulphate of potash	11.42	3.55
Nitrate of soda	16.58	3.90
Lime	13.05	3.22
Manure	15.50	3.56
Phosphoric acid and sulphate of potash	17.16	3.83
Phosphoric acid and nitrate of soda	10.50	3.40
Nitrate of soda and sulphate of potash	13.20	3.29
Phosphoric acid, lime, nitrate of soda, and sulphate of potash	7.06	2.45
Phosphoric acid, nitrate of soda, and sulphate of potash	12.35	3.18

Where manure, sodium nitrate, or lime was the single fertilizer the transpiration increased materially. Acid phosphate or potassium sulphate alone gave but a slight increase. The combinations of acid phosphate and potassium sulphate gave a large increase, but acid phosphate in the other combinations either decreased the transpiration or gave but little increase.

An experiment with Ceara rubber was carried out. The best results were obtained with lime, sodium nitrate, and the two combinations, sodium nitrate and potassium sulphate, and sodium nitrate, potassium sulphate, and acid phosphate. Manure alone and potassium sulphate alone gave fair results. Acid phosphate, except in the one combination already cited, gave poor results. These pot experiments indicate that sodium nitrate used alone makes a good fertilizer for rubber trees, while acid phosphate has some deleterious effect upon them.

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[a] U. S. Dept. Agr., Bur. Soils Circ. 18.

FIELD CROP EXPERIMENTS.

By F. G. Krauss.

The following subjects are treated in this report: Rice investigations, including tests of old and new varieties; fertilizer experiments, upland rice as a hay and grain crop, and salt marsh rice hay experiments; Chinese and Japanese mat rush experiments; cotton experiments; soy beans; peanuts; and Leghorn wheat.

RICE INVESTIGATIONS—REPORT OF SECOND YEAR'S EXPERIMENTS.

INTRODUCTION.

The rice experiments covering the past year are a continuation of the investigation begun two years ago. The work has thus far followed closely the original outline as set forth in A Preliminary Report on Rice Investigations. (See Pl. IV). In the search for rotation and substitute crops for our rice lands, a number of new crops are being tested. Among these may be mentioned the Chinese and Japanese mat sedges for the lowlands; cotton for the dry uplands; soy beans and peanuts for intermediate conditions.

A brief sketch of the rice industry in Hawaii appeared in the first report of these investigations.

Industrial and commercial statistics of the industry, compiled from original sources, are given herewith for reference.

THE MILLING INDUSTRY.

The milling of rice is not confined to the Chinese, as is the cultural phase of the industry. One of the largest and most modern of the rice mills is conducted by Mr. H. E. Walker in Honolulu. Another large modern mill is that of the City Mill Company, of which Mr. Chung K. Ai is manager. The Japanese Rice Mill Company is another large Honolulu concern which mills imported Japan rice exclusively.

The maximum capacity of the largest mills is about 100,000 bags of clean rice per annum. As two crops are harvested during the year, besides the large importations of Japan rice in the "brown," the larger mills are run during a large part of the year. The majority of the fifty odd mills in the islands are of antiquated Chinese pattern, the product of which does not equal the highly finished American article, which is not sought by the oriental trade of Hawaii.

Below is given a list of the principal Hawaiian rice mills having a capacity of 10,000 or more bags clean rice per annum. Honolulu is the principal milling center.

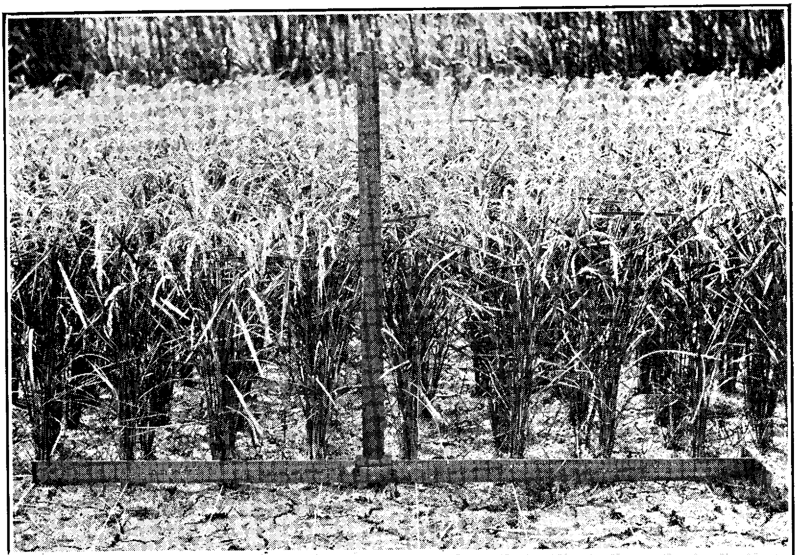
Principal rice mills of Hawaii.

Name of mill.	Location.	Type of Mill.	Approximate capacity (clean rice)	Kind of Rice. milled.	
				Hawn.	Japanese
	OAHU.		*Bags.*	*Bags.*	*Bags.*
City Mill Co	Honolulu	Modern	45,000	15,000	30,000
C. Ah Loong Mill	do	Antiquated	10,000	7,000	....
Iwilei Rice Mill	do	do	10,000	10,000	....
Japanese Rill Mill Co.	do	Modern	100,000	....	100,000
Kaalaea (Sing Chong Co)	Heeia	Antiquated	13,000	13,000	....
Kaneohe Rice Mill Co. Ltd	Kaneohe	Modern	16,000	16,000	....
Kimura S. Rice Mill	Honolulu	do	20,000	....	20,000
Waialua Rice Mill (Sing Chong Co)	Pearl City	Antiquated	26,000	26,000	....
Walker's Rice Mill	Honolulu	Modern	68,000	3,000	65,000
Wing Chong Can Co	do	Antiquated	14,000	14,000	....
Wong Kwai Mill	Punaluu	do	12,000	12,000	....
Wong Leong Rice Mill	Waimanalo	do	11,000	8,000	3,000
	KAUAI.				
Hee Fat	Hanalei	....	4,200	....	....
Hee Fat	Kapaa	....	11,250	....	....
Man Sing Co	Hanalei	....	11,000	....	....
Pah On Mill	Waimea	....	16,000	....	....

The total yield of rice on the Island of Hawaii does not exceed 11,000 bags clean rice per annum. The Palolo Rice Mill Kohala, mills about 3,000 bags; Waipio Rice Mill at Kukuihaele, mills about 6,000 bags; Halawa Rice Mills, about 2,000 bags. The island of Maui grows and mills less than 5,000 bags and Molokai only about 500 bags per annum.

Comparatively little of the 50,000,000 pounds of rice grown in Hawaii is exported from the islands. The imports of Japan rice are large. The amount of rice imported from the United States is about equal to that exported from Hawaii.

PLATE IV. Fig. 1. Uniform planting in rice experiments.



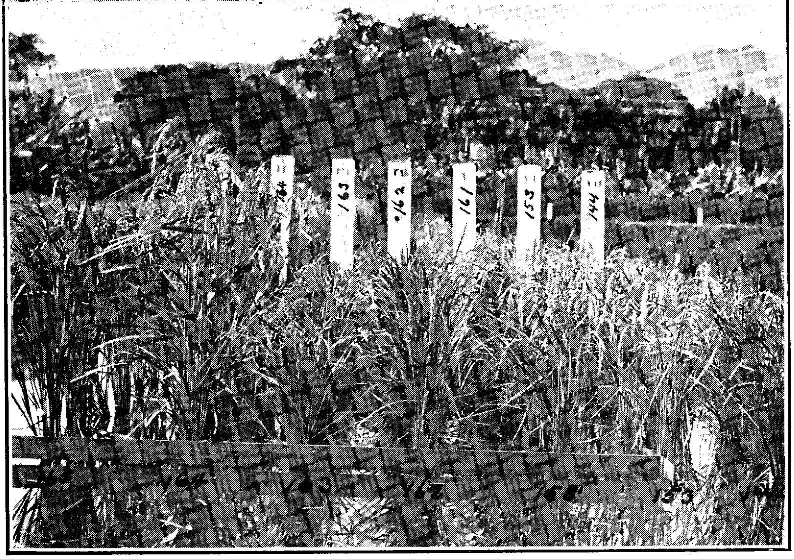


Fig. 2. Seven types of Japan rice

Below are given the U. S. customs statistics covering the imports and exports of rice to and from Hawaii for the five years ending June 30, 1907.

Imports of rice into Hawaii.

Year.	Japan.		China.		United States.	
	Amount.	Value.	Amount.	Value.	Amount	Value.
	Pounds.	*Dollars.*	*Pounds.*	*Dollars.*	*Pounds.*	*Dollars.*
1903	10,194,030	234,273	58,125	926	2,209,920	102,008
1904	19,044,460	443,920	341,113	4,449	3,642,925	143,142
1905	9,656,796	221,116	11,964	245	9,983,491	303,029
1906	12,496,396	283,653	22,600	529	4,129,643	164,683
1907	21,012,842	539,021	13,906	351	755,050	34,144

The exports to the United States from Hawaii during the same period were:

Exports of rice to the United States from Hawaii.

Year.	Amount.	Value.
	Pounds.	*Dollars.*
1903	234,930	$10,218.00
1904	31,911	1,610.00
1905	2,771,083	84,414.00
1906	5,739,500	223,012.00
1907	3,324,107	147,439.00

Acknowledgement is made of the valuable assistance and coöperation of rice planters, station workers, and others who have aided in the past year's experiments. The station's thanks are also due the Hawaiian Fertilizer Company and The Pacific Guano and Fertilizer Company, of Honolulu, for their liberal donation of fertilizers used in the past two year's experiments.

TEST OF OLD AND NEW VARIETIES OF RICE.

During the past year a third comparative test was made of some 130 varieties of rices originally obtained from the U. S. Department of Agriculture through the Office of Experiment Stations. This experiment completes two fall and one spring test of a representative list of varieties. Another spring test is planned for 1909 and the data of the four tests will be compiled in the form of a classified descriptive list.

The past season was favorable to growth and the same general cultural methods were adopted as in former tests. As in the two preceding tests, all the stocks were selected from individual mother plants; two such selections were sown of each variety, the object being to double the range of selection. On the whole, this test again demonstrates the good results to be obtained from careful selection.

As in the previous tests, all the varieties came true to type, thus confirming our original observations that natural hybridization does not readily take place in the field.

While a number of varieties might be eliminated at this time, it seems best that a fourth and final test be made before discarding any of the varieties now under test.

During the year, pure strains of the most promising varieties of last year were grown in quantity and disseminated among the rice growers generally. Of these, variety No. 19 (S. P. I. Inv. No. 12508), said to have been experimentally grown at the Georgetown Botanical Gardens from imported Ceylon stock, has thus far proved the most noteworthy. This variety proved very uniform in type from the start. The mother plant, selected from among the first progeny, produced 26 fruiting culms, which yielded 59 grams paddy, numbering 1,176 seeds. Two hundred plants in the test row produced over 17 pounds of paddy; and 10 pounds of stock seed transplanted to one-third acre, yielded 1,680 pounds choice paddy, on unfertilized land. This represents an increase of 168 fold and an acre yield of 5,040 pounds paddy under field conditions.

The culinary qualities of rice No. 19 are excellent. The milled grain is long, slender, hard and translucent, a type highly prized by the Chinese upper class. Considering the type, the milling qualities are fair, the paddy yielding about 62 per cent of prime rice. This rather large loss in milling is principally due to the unusually long slender grains which fracture in the process of hulling.

Variety No. 19 is suitable for fall culture only. July and August plantings mature in from 120 to 140 days. When planted in the spring it continues to vegetate till late in the fall and matures with late planted crops. As this variety tillers extraordinarily, 80 fruiting culms having been obtained from a single seed, with 25 as an average, not more than two or three seedlings should be set in a clump at transplanting.

A carefully developed strain of Japan rice, No. 153, now in its fourth generation of selection, is meeting with much favor among the several growers who have tried it. It matures in 110 days from planting, and yields equally with the more slowly maturing Hawaiian type of Gold Seed. The Japanese, who are the principal consumers of the Japan Seed rice, appear to regard the locally grown product with less prejudice, as its quality becomes better known.

In this connection, the chemical composition of the Japan and Hawaiian grown stocks is of interest. It was claimed by the Japanese that the local product lacked in "strength," "richness," and "fattiness," as well as flavor. The following analyses were made by the Bureau of Chemistry, U. S. Department of Agriculture, and confirm the analyses made by this station:

Chemical analyses of imported and Hawaiian grown Japan rices.

	Moisture.	Protein (N x 6.25)	Fat.	Carbohydrates by difference.	Crude fiber.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Imported Japan (in brown)...	10.97	7.19	2.08	77.53	1.02	1.21
Hawaiian grown Japan (in brown).........	10.40	7.38	2.23	77.26	1.07	1.66
Imported Japan (fully milled)	11.16	6.63	.38	80.91	.46	.49
Hawaiian grown Japan (fully milled).........	10.76	7.31	.58	79.93	.60	.82

A comparison of the above data shows that instead of being inferior to the imported product, the Hawaiian grown Japan rice contains a higher percentage of fat and nitrogenous matter, the properties that would seem to determine the so-called "richness," "fattiness," and "strength."

A selection from variety No. 39 (S. P. I. Inv. No. 12582), a Georgia strain of Gold Seed, continues to gain headway against the Hawaiian type of this standard form of rice.

Variety No. 65 (S. P. I. Inv. No. 17144), the Egyptian variety similar to the Japan type, maintains its excellent yielding qualities, but is not liked by the Japanese consumers, who claim that it lacks in flavor. Besides, it is slower in maturing than the Japan sorts, which now produce satisfactory yields. However, this variety is especially well adapted for use as a hay crop, it is nutritious, the hulls of the seed are smooth, and the kernel is soft. It succeeds well with a minimum amount of irrigation. At a lower price than is asked for standard sorts, large quantities of the grain would be used in the manufacture of the Japanese food product, "Miso."

Variety No. 152, the Ay-Yujip rice, from the Igorrote country, Philippine Islands, which gave exceptional promise in the first comparative test, failed utterly in an extensive planting at Punaluu, along side of variety No. 19. While the general growth was satisfactorily, it failed to set seeds. Grown at the trial grounds near Honolulu, the results, while not equal to the first test, were fairly good. No explanation can be offered for this difference in behavior except that the excessive winds prevailing during the flowering season may have prevented pollination. No. 73, a Philippine rice called "Mokalit," of the Chinese "No-mai" type, also yielded well.

Five new Japan rices, three of which, Nos. 161, 162, and 163, were kindly sent to the station by Dr. Y. Otsuka, Chief of the Kiushu Agricultural Experiment Station, at Kumamoto, Japan; and Nos. 164 and 165, which were presented to the station by Mr. McQuaid, of the Kona Developing Company, Island of Hawaii, who secured them from Japanese farmer at south Kona, were tested in comparison with the two Japan varieties previously grown (Nos. 144 and 153). (See Plate V). All the varieties made a good growth and are considered promising. Of these, variety No. 164 has given splendid results both in submerged and upland culture, and a half acre is being grown in two widely separated localities this year. Variety No. 165 is also a heavy yielder, doing well under both dry and wet land culture, but its opaque kernel, which limits its use to the "Mochi-gomi" of the Japanese, and "No-mai," or cake flour, of the Chinese, will prevent its extensive planting, except possibly as a stock feed or for the manufacture of "Miso."

The following milling test was made by the City Mill Company at Honolulu:

	Prime Rice	Broken Rice.
	Per Cent.	*Per Cent.*
Rice No. 19	62	4.0
Rice No, 39	61	3.0
Rice No. 65	67	1.0
Rice No. 73	67	1.0

Better results would perhaps be obtained on large quantities of rice.

The upland rices, Nos. 65, 68, and 154a, yielded slightly less during the past year than the year previous, but a good quality of stock seed was secured. Nos. 67 and 154b have been discarded as inferior to the other varieties.

Pure strains of stock seed of Nos. 19, 39, 65, 68, 73, 153 and 154a, are now available for distribution. (See Pl. V).

FERTILIZER EXPERIMENTS.

EXPERIMENT I. RESIDUAL FERTILIZER EXPERIMENT.

The object of this experiment was to determine the residual value upon the spring crop of Japan and Gold Seed rice, of fertilizers that were applied to the previous fall crop. The experiment is a continuation of "fertilizers experiment III" (1907), which is reported in detail in the first report of rice investigations.[a]

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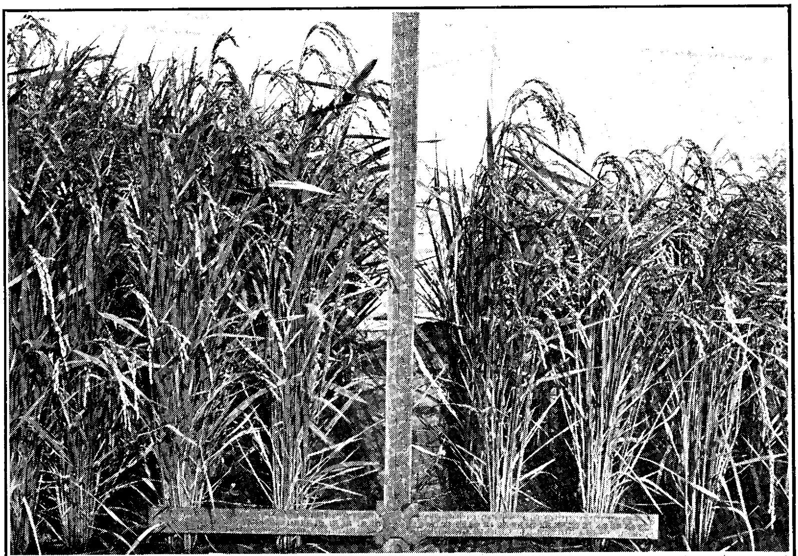
[a] Hawaii Sta. Rpt 1907, p. 81.

PLATE V. Fig. 1. Relative growth from equal amounts sulphate of ammonia (on left) nitate of soda (on right.)



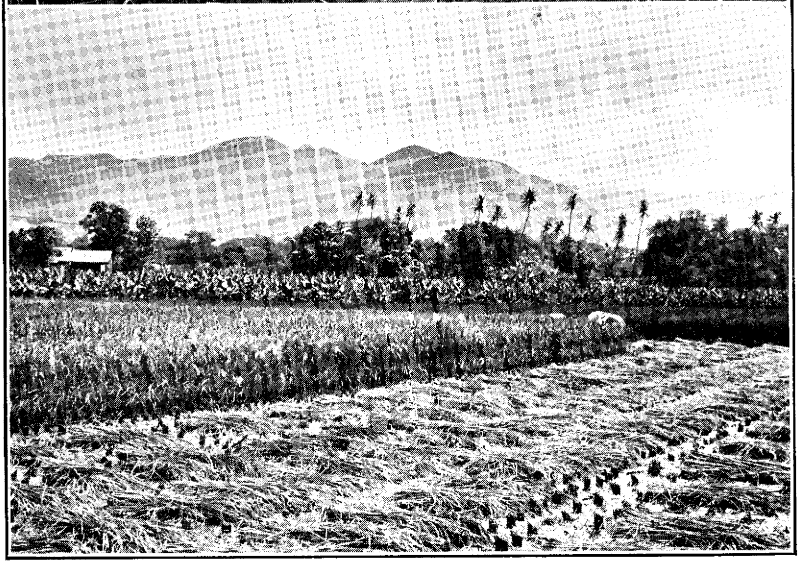


Fig. 2. Harvesting salt marsh rice for hay.

Owing to the depredations of rice birds upon the late maturing Gold Seed of the 1907 direct fertilization experiment, no comparative data are available for the corresponding variety in the residual experiment herein reported.

The following table gives the results of this experiment:

Relative residual value of the various commercial forms of fertilizers, on rice, paddy produced by 100 clumps of rice. (a)

Plat number.	Fertilizer applied.	Amount per acre.	Equivalent.	Check (untreated). Average of 10 plats.		Fertilized before planting.		Limed (750 lbs.) and fertilized before planting.		Fertilized after plants were three-fourths grown.	
				Japan Seed.	Gold Seed.	Japan Seed.	Gold Seed.	Japan Seed.	Gold Seed.	Japan Seed.	Gold Seed.
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1	Nitrate of soda	266	40 N	2.3	2.6	2.4	(*b*)	2.7	4.4	2.5	(*b*)
2	Sulphate of ammonia	200	40 N			2.5	3.8	2.5	4.0	3.3	4.6
3	Sulphate of potash	95	45 K_2O			2.3	2.7	2.4	3.3	3.1	4.5
4	Sulphate of potash and magnesia	180	45 K_2O 61 $MgSO_4$			2.3	2.7	2.4	3.2	3.4	4.7
5	Acid phosphate	125	25 P_2O_5			2.4	2.6	2.6	3.4	3.1	5.1
6	Reverted phosphate	156	25 P_2O_5			2.2	3.2	3.5	3.7	3.1	4.5
7	Thomas slag phosphate	156	25 P_2O_5 62 CaO			2.4	3.0	2.5	3.6	3.0	4.3
8	Complete fertilizer A (nitrate of soda, acid phosphate, and sulphate of potash)	350	28 N 17.5 P_2O_5 31.5 K_2O			2.3	3.7	2.4	3.8	2.6	4.5
9	Complete fertilizer B (sulphate of ammonia, fish guano, reverted phosphate, and sulphate of potash)	350	28 N 17.5 P_2O_5 31.5 K_2O			2.2	3.7	2.3	4.0	2.5	4.2
10	Complete fertilizer C (nitrate of soda, Thomas slag phosphate, and sulphate of potash and magnesia	350	28 N 17.5 P_2O_5 31.5 K_2O			2.3	3.0	2.5	3.0	2.6	4.0

(*a*) Results from materials containing a single fertilizer constituent not comparable with the complete fertilizers which contain only 70 per cent of the constituents applied singly, although the preparations are the same.

(*b*) Weight lost.

SUMMARY.

From the data given in the preceeding (allowing 0.3 pound for experimental error), it would appear that the Japan Seed received no residual value from any of the fertilizing materials when applied to the previous crop before planting; but that the Gold Seed was benefited to the extent of 34 per cent increase from the residual effects of sulphate of ammonia, 11 per cent from the reverted phosphate, 0.3 per cent from the Thomas slag phosphate, 30 per cent each from complete fertilizers A and B, and 0.3 per cent from complete fertilizer C.

When limed with 750 pounds of slacked lime in addition to fertilizing before planting, the Japan Seed failed to show any increase in yield, due to any of the treatments. On the other hand, Gold Seed appears to show decidedly increased yields under like conditions. This may be due to the more vigorous and longer period of growth characteristic of the latter variety, and would indicate that liming may prove beneficial when applied to a neutral soil, provided it is applied sufficiently in advance of planting the crop.[a]

The largest residual value was received by both varieties of rice when the fertilizers were applied to the previous crop when three-fourths grown. Thus allowing 13 per cent for experimental error, we get the following results:

Residual value of fertilizer materials when applied to the previous crop three-fourths grown.

Treatment.	Increase over untreated plats.	
	Japan Seed Paddy.	Gold Seed Paddy.
	Per Cent.	*Per Cent.*
Nitrate of Soda	00	* (*a*)
Sulphate of Ammonia	30	63
Sulphate of Potash	21	60
Sulphate of Potash and Magnesia	34	67
Acid Phosphate	21	83
Reverted Phosphate	21	60
Thomas slag Phosphate	17	52
Complete Fertilizer A[b]	00	60
Complete Fertilizer B[b]	00	48
Complete Fertilizer C[b]	00	40

* [a] Weight lost.

[b] Contains only 70 per cent of the constituents applied singly and therefore not comparable.

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[a] The application of lime to the previous crops lowers the yield in every instance. See Experiment III, Hawaii Sta. Rpt. 1907, p. 81.

EXPERIMENT II. RESIDUAL FERTILIZER EXPERIMENT (B).

This experiment is a continuation of pot fertilizer experiment II of the 1907 series.[a]

After lying fallow in the pots for six months, the originally fertilized soil was submerged under several inches of water, as is the custom in field culture. When thoroughly softened the mud was stirred to a depth of 4 inches and then left to settle.

Five 15-day-old seedlings of selected Japan Seed rice No. 153 were transplanted into each pot, three pots forming a series.

The plants grew well, and the paddy of all the series was harvested at one time, even though a few days difference in maturity was apparent in some of the series.

The residual value of the various commercial fertilizer materials as shown by pot cultures when the fertilizers were applied to the previous crop at the rate of fifty pounds per acre of each element, is shown below:

Residual effect of fertilizers in pot cultures with Japan rice.

Series.	Treatment.	Yield of paddy.	Series.	Treatment.	Yield of paddy.
		Grains.			*Grains.*
I	Check	5.1	X	Sulphate of ammonia and acid phosphate	5.8
II	Nitrate of soda and sulphate of potash	5.8	XI	Sulphate of ammonia and Thomas slag phosphate.	6.5
III	Nitrate of soda and muriate of potash	5.9	XII	Fish guano and acid phosphate	5.2
IV	Sulphate of ammonia and sulphate of potash	7.0	XIII	Fish guano and Thomas slag phosphate	5.3
V	Sulphate of ammonia and muriate of potash	5.6	XIV	Acid phosphate and sulphate of potash	5.7
VI	Fish guano and sulphate of potash	7.3	XV	Acid Phosphate and muriate of potash	[a]
VII	Fish guano and muriate of potash	5.8	XVI	Thomas slag phosphate and sulphate of potash.	5.4
VIII	Nitrate of soda and acid phosphate	6.0	XVII	Thomas slag phosphate and muriate of potash	[a]
IX	Nitrate of soda and Thomas slag phosphate	5.9	XVIII	Equivalent proportion of each element in each of the forms represented above	[b]

(*a*) Weight in doubt. (*b*) Plants failed to mature.

SUMMARY.

In the 1907 direct fertilizer experiment, one pot of each series had been limed and one drained, while the third received no other treatment than the application of fertilizer. In the direct fertilizer experiment, the limed pots in every series showed some depression, varying from 14 to 40 per cent in the decreased yield of straw and paddy. In the residual experiment no such depression was noticeable due to liming, the lime evidently having been neutralized in the meantime. All the pots of a series showed uniformity in growth. It could not be noticed that draining the pots exerted any influence upon the yield. The loss of fertility due to leaching was apparently insufficient to influence the growth.

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[a] Hawaii Sta. Rpt. 1907, p. 80.

The results of the experiment seem to indicate that the largest residual value was derived from the fish guano and sulphate of potash (Series IV). The next best result seemed to have been obtained from sulphate of ammonia and Thomas slag phosphate (Series XI), nitrate of soda and acid phosphate gave better results than sulphate of ammonia and acid phosphate (Series VIII), nitrate of soda and muriate of potash, and nitrate of soda and Thomas slag phosphate, gave equal results (Series III and IX). It is difficult to understand why the fish guano in combination with acid phosphate and Thomas slag should have given the poorest results in the whole experiment, while the fish guano and phosphate gave good results in other combinations.

From the above experiment, it would appear that considerable residual value may result from the application of moderate quantities of some of the commercial fertilizer materials, even when applied to the previous crop before planting.

In residual experiment the quick maturing Japan Seed derived little or no benefit when the preceding crop was fertilized before planting, but the more vigorous and slowly maturing Gold Seed showed increased yields up to 34 per cent under the same treatment. However, when the previous crop was fertilized after the crop was three-fourths grown, material benefit was derived by both the Japan Seed and Gold Seed, the strong growing Gold Seed receiving the greatest benefit.

So far as the two experiments are comparable, there is agreement in the general principle involved, i. e., that chemical fertilizers may exert influence upon succeeding crops and that such influence depends upon the amount and period of its application. It may further be concluded :

(1). That nitrogen in sulphate of ammonia, and in the organic form; phosphoric acid in the water soluble, reverted and tetra calcic forms; and potash as a sulphate and a muriate, may exert residual value when applied in sufficient quantities before planting the preceeding crop, the stronger and more vigorous growing variety deriving the greater benefit.

(2). That the same fertilizers, in like quantity, applied to the crop first preceding when well advanced in growth, will exert a considerably greater residual benefit upon the succeeding crop than if applied before planting.

It has already been determined in a former experiment, that, with the single exception of nitrate of soda, fertilizer materials exert the greatest benefit to the immediate crop when applied before planting.

Thus may we conclude that, while fertilization before planting benefits the immediate crop most, the greatest residual benefit is derived from fertilizers applied to the previous crop when well advanced in growth.

Thus it will be seen that each method has an advantage as well as a disadvantage. The relative economy of the two methods of fertilization has not yet been determined, but from the experimental data thus far accumulated, and from the well-known fact that the spring crop is naturally the lighter where two crops are grown annually, and responds most to fertilization, it would seem that liberal applications of fertilizers applied to the spring crop, before planting, would produce the maximum spring yield and carry over sufficient residue to give a maximum fall crop without additional fertilizer, or, if a stimulant should be needed as the fall crop advances, a light application of sulphate of ammonia or nitrate of soda might be applied at the drying off period preceding the flowering stage. An experiment is now under way to determine these points.

EXPERIMENT III. DIRECT FERTILIZER EXPERIMENTS.

Three tests to compare the relative value of several commercial forms of nitrogen as fertilizers for the rice crop were made during different seasons of the year.

The subjoined table gives the results of the first series of these tests together with the results obtained from green manure, stable manure, and the complete rice fertilizer recently formulated by the station.

This series of tests was made under identical season, soil, and cultural conditions, so that the results are comparable and represent the yield of paddy from 100 clumps of rice.

Relative value of various forms of nitrogen for rice.

Plat Number	Fertilizer applied.	Amount per Acre	Height of plants at maturity.	Green weight whole plants	No. of culms per clump of five plants.	Weight of paddy	Date of maturity.
		Pounds.	*Inches,*	*Pounds.*		*Pounds.*	
I	Check (no fertilizer)...	....	33-35	45	15-20	5.3	July 20
II	Complete fertilizer *a*	350	38-40	48	20-22	7.1	July 22
III	Stable manure............	5000	40-45	55	21-23	6.8	July 25
IV	Complete fertilizer *b*	350	40-43	51	20-25	7.9	July 20
V	Check.......	....	34-35	46	17-20	5.7	July 22
VI	Green manure............	20000	40-48	60	20-25	5.9	July 30
VII	Sulphate of Ammonia	200	44-48	64	25-27	8.1	July 25
VIII	Lime Nitrogen..	266	38-42	50	22-24	6.7	July 25
IX	Check............................	....	30-34	44	16-18	5.2	July 20
X	Nitrate of soda...........	266	35-38	47	20-22	5.9	July 28

a. Applied when the crop was two-thirds grown.
b. Applied before planting.
Balance of fertilizers, except stable manure and green manure, applied to crop when two-thirds grown.

SUMMARY.

In the test of the nitrogenous fertilizers, nitrogen was applied at the rate of 40 pounds per acre, when the crop was one-half to two-thirds grown, the materials being applied broadcast upon the receding flood water which precedes the drying off period, a short time before the rice comes into bloom. (See Pl. IV).

The increase in yields of paddy over untreated plats was as follows: With sulphate of ammonia, 50 per cent; lime nitrogen, 24 per cent; nitrate of soda, 9.2 per cent.

The green manure (legumes and weeds) yielded only 9 per cent increase in paddy, but a large increase in straw, the small yield of paddy being due to an excessive rankness of growth, in which the seed set poorly. The green manure was applied at the estimatel rate of 20,000 pounds per acre, and was worked into the submerged soil just previous to planting, as is the custom in Oriental countries, and it is probable that the material was applied at too short an interval before planting, or in quantities excessive for the amounts of mineral matter available.

A further observation illustrates the danger of excessive green manuring.

The green manure plat showed rankness in growth especially along the outer rows, adjoining the dikes where an extra amount of vegetation had unavoidably accumulated.

The first and outer row failed to set fruit, although it flowered and tillered freely; the second row showed less rankness, and seeded fairly well. Irregular ripening characterized the fruiting panicles; rows 3 to 5 were fairly uniform in height, fresh weight, yield of paddy, and maturity.

Compared with the results obtained from sulphate of ammonia, the green manure produced plants of about equal height, but less tillering, slower maturity and less uniformity. The 5,000 pounds stable manure per acre gave 26 per cent increase in yield of paddy. The complete fertilizer yielded 31 per cent increase when applied to the crop two-thirds grown, and 46 per cent when applied before planting. This latter fertilizer supplied 17½ pounds of nitrogen per acre.

EXPERIMENTS IV AND V.

In experiments 4 and 5 the comparative value of different forms of nitrogen for Japan and Hawaiian Gold Seed rice and for different varieties of Japan rice was tested. In each case the yield of 100 clumps of rice was taken. The acompanying tables give the results of the experiments:

Relative value of commercial forms of nitrogen as fertilizers when applied to Japan Seed and Hawaiian Gold Seed rice.

	Amount per acre.	Japan Seed.		Hawaiian Gold Seed.	
		Yield of paddy.	Increase.	Yield of paddy.	Increase.
	Pounds.	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
Check (average of 3 plats)	....	2.6	....	3.1	....
Nitrate of soda	266	2.8	7.6	3.3	6.4
Sulphate of ammonia	200	4.1	57.6	5.2	67.7
Lime nitrogen	266	3.0	15.8	4.1	32.2

Relative value of different commercial forms of nitrogen as fertilizers when applied to various types of Japan rice at an early stage of growth.

Variety No.	Fertilizers applied (equivalent of 40 pounds nitrogen).						
	Check. (average of 2 plats).	Sulphate of ammonia.		Nitrate of soda.		Lime-nitrogen.	
		Yield of paddy.	Increase over check.	Yield of paddy.	Increase over check	Yield of paddy.	Increase over check.
	Pounds.	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
144	2.15	2.94	37	2.30	7	2.64	22
161	4.06	6.00	48	4.54	12	5.30	31
163	4.50	6.47	44	5.35	19	5.80	28
165	5.20	7.33	41	5.93	14	6.62	28

In both these experiments, the sulphate of ammonia proved the most beneficial, lime nitrogen second, and nitrate of soda third. These results are in agreement with the former test.

In experiment 4, the Japan and Gold Seed were grown under identical conditions, but the Japan Seed matured in 110 days while the Gold Seed matured in 140 days. This longer period of growth after fertilization evidently acted favorably in the case of the sulphate of ammonia and the lime nitrogen, but made little or no difference in the case of the nitrate of soda.

Thus it would appear that the maximum benefit from nitrate of soda may be secured from a comparatively late application, while the sulphate of ammonia, and especially the lime nitrogen, require a considerably longer period in which to exert their maximum power. Furthermore, it is evident that when applied in large quantities, either early or late, but a small percentage of the nitrogen in nitrate of soda is taken up by the plant.

FERTILIZER EXPERIMENTS ON DRYLAND RICE.

The fertilizer tests upon dry-land rice resulted in indefinite results as regards the yield of paddy, owing to the unusually dry season. However, on both the silty loam of the station grounds and the gravelly loam of the rice trial grounds the muriate of potash, sulphate of ammonia, and nitrate of soda increased the yield of straw in the order named. The other constituents applied in the same forms and amounts as shown in table on page 71, appeared to exert no influence.

CO-OPERATIVE EXPERIMENTS WITH A COMPLETE FERTILIZER

Three cooperative tests with a complete fertilizer were undertaken on three separate plantations.

The fertilizer was of the following composition:

5 per cent nitrogen—2 per cent as organic (fish guano and dried blood), 3 per cent as sulphate of ammonia.

9 per cent phosphoric acid—4 per cent as acid phosphate, 5 per cent as reverted phosphate.

12 per cent potash as sulphate of potash.

The fertilizer was applied at the rate of approximately 350 pounds per acre. This is equivalent to 17.5 pounds nitrogen, 31.5 pounds phosphoric acid, and 4.2 pounds potash per acre. The cost of this mixture in the Honolulu market is about $50 per ton, hence the cost of fertilizing, including transportation and application, approximates $10 per acre.

The results from these experiments were as follows:

At Punaluu Plantation, Oahu, which has been continuously under rice since 1872, the average yield on 37 acres has been less than 74,000 pounds paddy per spring crop. Five tons of the above formula was applied to the 37 acres, and the increased yield of paddy, covering the whole area, was estimated at 35 per cent over the average of former crops.

Valuing the paddy at $2.25 per hundred pounds and making a liberal allowance for the cost of fertilization, a net profit of $6 per acre was obtained upon the first crop. As the fertilizer was applied to the crop when it was two-thirds grown, a considerable residue should be conveyed to the subsequent crop.[a]

In a second experiment adjoining the rice trial grounds at Waikiki, a one-year fallow paddy field was set to Hawaiian Gold Seed on March 2. On May 1, the complete fertilizer was applied to half the field at the rate of 350 pounds per acre. The crop was harvested the latter part of June with the following results: Unfertilized, 2,950 pounds paddy per acre; fertilized, 4,100 pounds paddy per acre.

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[a] For former experiments conducted on this plantation, see Experiments V, VI, VII, Hawaii Sta. Rpt. 1907.

This gives an increase in yield of 39 per cent, which is equivalent to a net profit of $15 per acre after deducting $10 for fertilization.

In a supplementary test adjoining the above experiment, 200 pounds sulphate of ammonia (40 pounds nitrogen) gave an increased yield of 50 per cent over the unfertilized plats, an increase of 5 per cent over the plat receiving complete fertilizer. From this we may conclude that a higher percentage of nitrogen in the complete fertilizer would have yielded better results.

A third cooperative experiment yas conducted at Palama Plantation near Honolulu. The paddy field used had been cropped for twenty years and represented the poorer "kula" lands (uplands immediately bordering the better lowlands). The average yield was said to be less than 1,800 pounds paddy per acre. The complete fertilizer was applied to the crop shortly after planting, at the rate of between 350 and 400 pounds per acre. The estimated increase in yield was between 75 to 100 per cent over the unfertilized field. Owing to the crop being cut before a representative of the station arrived, no actual weighings could be made. The estimate was made by the planter. Based upon the results of this experiment, the station was called upon to plan a scheme for the systematic fertilization of the whole plantation.

UPLAND RICE AS A HAY AND GRAIN CROP.

The experiments with upland rice grown under minimum amounts of irrigation water are now in their second year and have given results which are summarized below.

Of the eight or ten varieties of upland rice entering into the first comparative tests, all have been eliminated except variety No. 68 (S. P. I. Inv. No. 17917), a dwarf, bearded rice from northern China, which matures in 100 to 115 days; variety No. 65 (S. P. I. Inv. No. 17144), a strong growing smooth hulled, beardless type, of Egyptian origin, extensively known in Louisiana as "Bull Rice"; No. 154a, a Porto Rico upland rice resembling the Gold Seed; and possibly No. 19 (S. P. I. Inv. No. 12508), the Ceylon rice described under variety tests, and which promises well under ordinary submerged culture.

A spring, summer, and fall planting gave the following mean results:

Summary of mean results obtained with a minimum amount of water upon upland rice.

Variety.	Method of planting.	Length of growing season.	Total water received. (irrigation and rainfall)	Yield of paddy.	Yield of hay (approximate)
		Days.	*Acre Inches.*	*Pounds.*	*Pounds.*
No. 19 (S. P. I. Inv. No. 12508)	Drilled	190	47.0	......(*a*)	10,000
No. 65 (S. P. I. Inv. 17144)	"	143	30.6	5,014	9,926
No. 68 (S. P. I. Inv. 17917)	"	109	23.5	2,080	5,920
No. 68 (S. P. I. Inv. 17917)	Aftermath	34	5.9	......(*b*)	2,240
No. 154 (*a*)	Drilled	145	30.0	......(*b*)	5,000

In the above data, the rainfall is included with the irrigation water, which was applied bi-weekly at the rate of approximately 2½ acre inches per application. This is equivalent to about 0.2 inches per day during the growing period.

When double the above amount of water was used, i. e., 2½ acre-inches weekly, the yield of hay was increased from 20 per cent in the case of varieties Nos. 65 and 68, up to 50 per cent with variety No. 19; but the grain was not increased proportionately.

When grown under submerged conditions, the yields of both paddy and hay failed to exceed those receiving weekly irrigations of 2½ acre-inches. With half the minimum amount of irrigation represented in the foregoing table, i. e., 2½ acre-inches once in four weeks, all the varieties suffered severely and failed to make a crop.

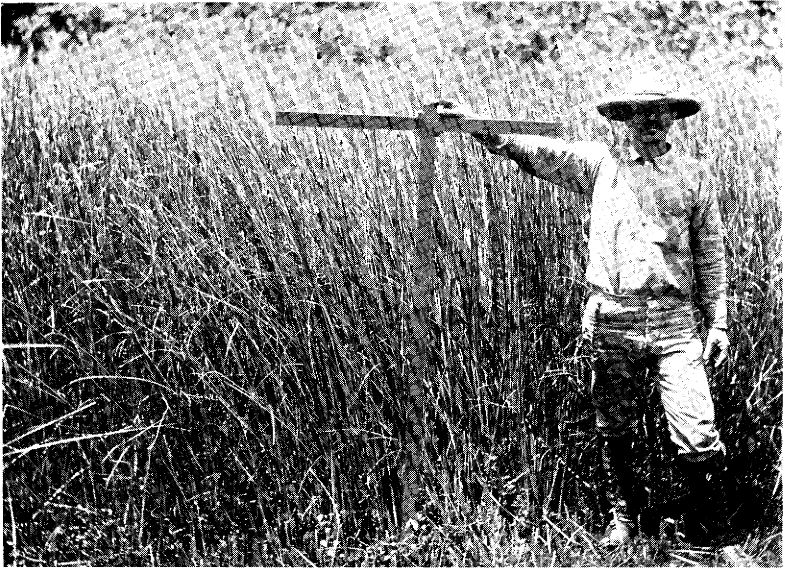
From the above we may conclude that 2½ acre-inches of water every two weeks during the growing season is the minimum moisture which will insure a paying crop, and the 2½ acre-inches of water weekly is near the optimum.

Two factors of equal importance in insuring a crop under a minimum water supply are deep and thorough tillage and light seeding. In a well tilled field, drilled at the rate of 60 pounls seed per acre, without irrigation, all the varieties failed to reach the fruiting stage under 10 inches of rainfall. However, when seedlings of the quick maturing variety No. 68 were thinned so as to stand 6 to 12 inches apart, in drills 8 inches apart, the plants tillered well and produced perfect seeds. Where the plants stood eight to the running foot, very little tillering occurred and only an occasional glume bore sparingly of seed. With sixteen seedlings to the running foot of drill (approximate stand from 60 pounds seed per acre), the plants entirely failed to set seed.

(*a*) Failed to set seed well.

(*b*) Not estimated.

PLATE VI. Fig. 1. Chinese mat rush, *(Cyperus tegetiformis)* five months from planting



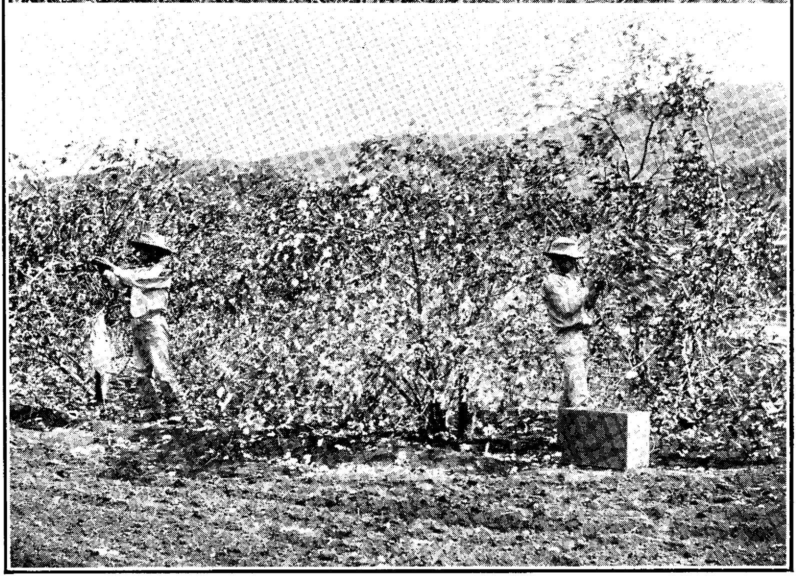


Fig. 2. Caravonica tree cotton at Hawaii Experiment Station.

Where the soil was poorly prepared, the plants made a much poorer growth than where the tilth was good. Under good tillage the development of the root system of one plant was equal to that of four to six plants in poorly prepared soil. The same relative development was true of plants set well apart and those that were crowded.

From this we may conclude that it is essential that the seed bed be thoroughly prepared and that the seed be sown thinly. The importance of this becomes greater as the supply of moisture becomes smaller.

Chemical analysis of the different varieties of rice entering into these experiments will be found in the report of the assistant chemist.

SALT-MARSH RICE AS HAY.

The price of imported cereal hays, exceeds $20 per ton, and the total importation is 10,000 tons, valued at a quarter of a million dollars annually. This fact has induced the station to devote some attention to developing a home-grown substitute. Much hope is entertained for upland rice in this regard. It has been further suggested that the inferior types of rices, such as the salt-resisting marsh varieties, which are now much used as adulterants in the standard sorts, might be utilized as a cured fodder for horses and cattle.

The following data have been obtained from an experimental harvest. Early in the spring an acre of growing marsh rice of average stand and quality was secured, adjoining the trial grounds.

The grain was in the milk stage May 20, when the flood water was drained from the field. On May 22 the ground was sufficiently firm to bear the weight of a man and the first cutting was made. Four days later most of the grain had entered the dough stage and another cutting was made. By May 30, most of the grain began to harden and the last harvest was made.

Calculated to acre yields, the following results were obtained:

Total green weight	14,212
Total air cured matter as hay	5,852
Total as cured paddy	2,842

At $25.00 per ton, the gross value would be $73.15 per acre as cured hay; and rating the paddy at $2 per 100 pounds, (a high price for this variety), its value would be $56.84 per acre.

The cost of harvesting for hay or grain would be about equal. The cost of curing and baling as hay should not exceed the cost of threshing and bagging the paddy. No special difficulty was experienced in securing a well cured hay, although the grain was found to shatter badly in the lot harvested when fully ripe. (See Pl. V).

Extensive feeding experiments have not yet been undertaken. However, it has been found that some horses feed greedily upon the well cured hay from the start, while others merely nibble the grain. The writer has fed a half ton to a horse and a cow with success, and the Chinese rice growers feed it almost exclusively to their horses; frequently they feed the straw alone.

Estimating the salt-marsh lands of Oahu now devoted to this type of rice at 1,000 acres, and allowing $10 increase revenue per acre by cutting the crop as hay, $10,000 per crop or $20,000 per annum could be added to the profits of the rice growers. A number of practical feeding tests are to be undertaken this fall.

CHINESE AND JAPANESE MAT RUSH EXPERIMENTS.

The species represented in these experiments are *Cyperus tegetiformis,* the Chinese mat rush (Seaside grass, Pl. VI), and *Juncus effusus,* the Bingo-i mat rush of Japan. Three plantings and three harvests have thus far been completed at the rice trial grounds near Honolulu, and a first planting at Kailua, on the windward side of Oahu. Each succeeding crop has been better than the previous one and the following results represent our best yields. In three average cuttings of 100 square feet each the Chinese mat rush yielded cured reeds at the rate of:

	Pounds per Acre.
60 inches and over	8,712
48 to 60 inches	5,762
36 to 48 inches	5,227

It required between 6 and 7 months for the spring crop to mature from direct planting. The fall crop matures in about 5 months when grown from rattoons. This second crop does not attain the length of the planted crop but the stand is more dense. The crop at Kailua is not yet mature, but promises well.

Sample reeds of the Chinese rush have been forwarded to a matting factory and reports as to quality are expected shortly. The Japanese mat rush has greatly improved during the past year and presents a fine appearance at this writing. A large stock of plants have been propagated and it is planned to set out several acres during the coming fall.

The greatest obstacle in the way of making the growing of the Chinese rush a profitable crop in Hawaii appears to be the large expense attached to preparing the rushes for market. Each reed requires to be split lengthwise before curing.

COTTON EXPERIMENTS.

Stray cotton plants appear in many parts of the Hawaiian group. As long ago as 1856, F. A. Oudinot reported[a] upon a cotton tree growing at Lahaina, Maui, which was said to be fifteen years old at that time. The variety is stated to be the Sea Island. Several attempts have been made to grow cotton upon a commercial scale, but the industry was never developed. Renewed interest at this time is very pronounced. A first variety test of cotton was made by the station in 1905-6. The quality of several of the varieties was favorably reported upon by the fiber experts of the U. S. Department of Agriculture and also by manufacturers.

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[a] Trans. Roy. Hawaii Agr. Soc., 2. (1860), No. 3, pp. 104-106.

A number of three-year-old pants of the Caravonica type are still growing on the station grounds and bear a fair quality of cotton. A recent experimental picking yielded 15 pounds seed cotton from a single plant. The plants bear continuously throughout the year. Some of the plants are being cut back to determine the influence of pruning. The kidney, silk, and wool Caravonica plants at the station are now three years old. (See Pl. VI). The plants will average at least 5 pounds per tree, and two such pickings can be made annually.

Beginning in March of the present year, a variety test was undertaken with two strains of Sea Island, two types of Caravonica, and a Chinese type of upland cotton. At the end of the fiscal year, June 30, the Sea Island was well in bloom and all the varieties were doing finely.

SOY BEANS.

The soy bean possesses many advantages as a green manuring or rotation crop. Early in the present year, three varieties of soy beans were obtained through the Bureau of Plant Industry. These were designated at Nos. 20797, 20798, and 21080. All were supposedly tall-growing varieties, which had been introduced into the Southern States as fodder and green manuring crops. Seed of two other varieties were donated by the Hawaiian Yamajo Soy Company of Honolulu. One of these, a green seeded type, has been grown in the Kona district of Hawaii for some years; the other, a yellow seeded variety, was imported direct from Japan. The seed of both of these varieties is used in the manufacture of the Japanese food product, "Miso," and other preparations.

All the varieties were sown on March 12. Variety No. 21080, which proved to be a dwarf type suitable for shelled beans, and the two Japan sorts matured in about 100 days from planting, (see Pl. VII, fig. 2). Planted in drills 12 by 18 inches apart, the following yields of shelled beans per acre were obtained:

Variety No. 21080, 600 pounds of shelled beans per acre; imported Japan, 800 pounds; and Kona seed, 1,060 pounds.

The plants of the above varieties are very dwarf, average less than 12 inches in height, and are upright in growth. It seems likely that closer planting, say 6 inches apart in the drill, will give material increase in yields. The average price in the Honolulu market is $3 per hundred pounds. About 500 tons of the beans are imported from Japan annually, and the demand is said to be on the increase.

It would appear that this could be made a profitable crop for the small farmer. The plant requires little moisture, but responds well to thorough hand tillage, which permits of close planting. Careful selections have been made and it is hoped that more prolific strains will be developed.

The tall-growing varieties are making a vigorous growth and have attained a height of from 10 to 30 inches. (See Pl. VII, fig. 1), The plants appear to be very irregular in size and maturity, as if the types had not been established. Two hundred pods have been counted on single plants, while others have not come into flower. All the varieties appear to be well supplied with root nodules.

PEANUTS.

Variety and cultural tests of the following varieties of peanuts are now under way: Spanish, Bunch Jumbo, Running Jumbo, and Virginia Running. Three types of soil at different elevations, and with varying amounts of soil moisture are being considered. Planted April 20, the varieties are making fine growth and flowering profusely June 30. The plants have made a spread of fully 4 feet.

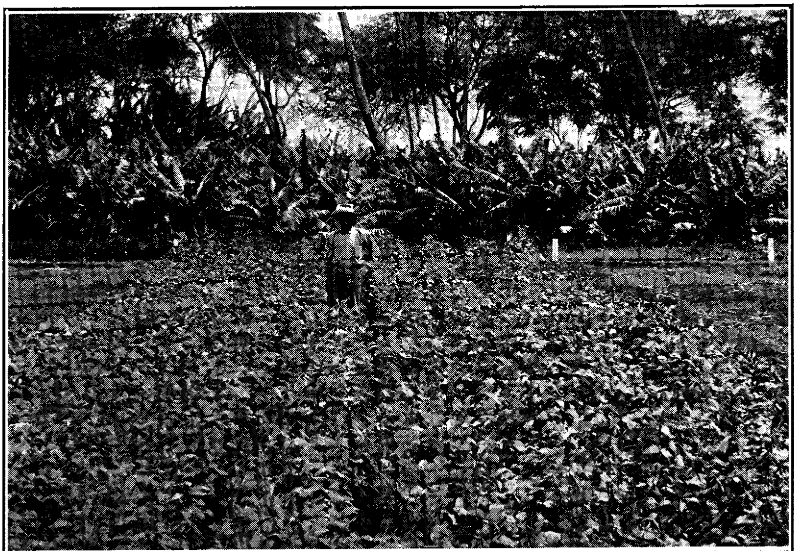
LEGHORN WHEAT.

A small quantity of seed of the wheat, the straw of which is used in the manufacture of the Italian Leghorn hats, was received under the name "Corn, Suta Fiore."

Drilled in rows 12 inches apart on March 23, the culms attained a height of 36 to 40 inches up to June 30. The plants tiller well and appear to require about as much moisture as upland rice.

PLATE VII.

Fig. 1. Plat of Soy Beans



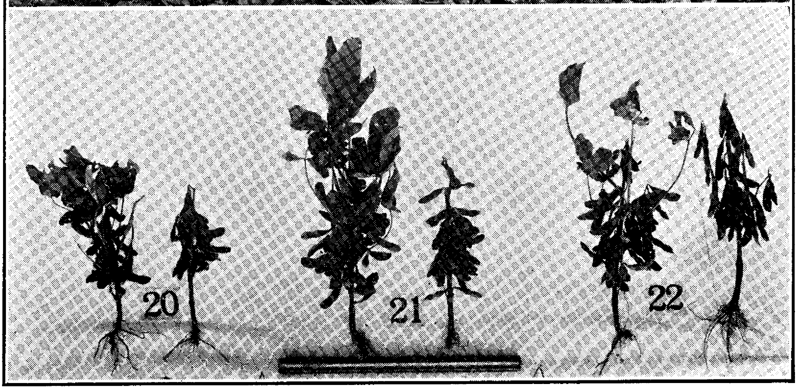


Fig. 2. Dwarf Soy beans, used in making "Miso" and other Japanese food products.

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Issued May 6, 1911.

HAWAII AGRICULTURAL EXPERIMENT STATION,

E. V. WILCOX, Special Agent in Charge.

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ANNUAL REPORT

OF THE

HAWAII AGRICULTURAL EXPERIMENT STATION

FOR

1910.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

An. Rpt. Hawaii Agr. Expt. Station, 1910.

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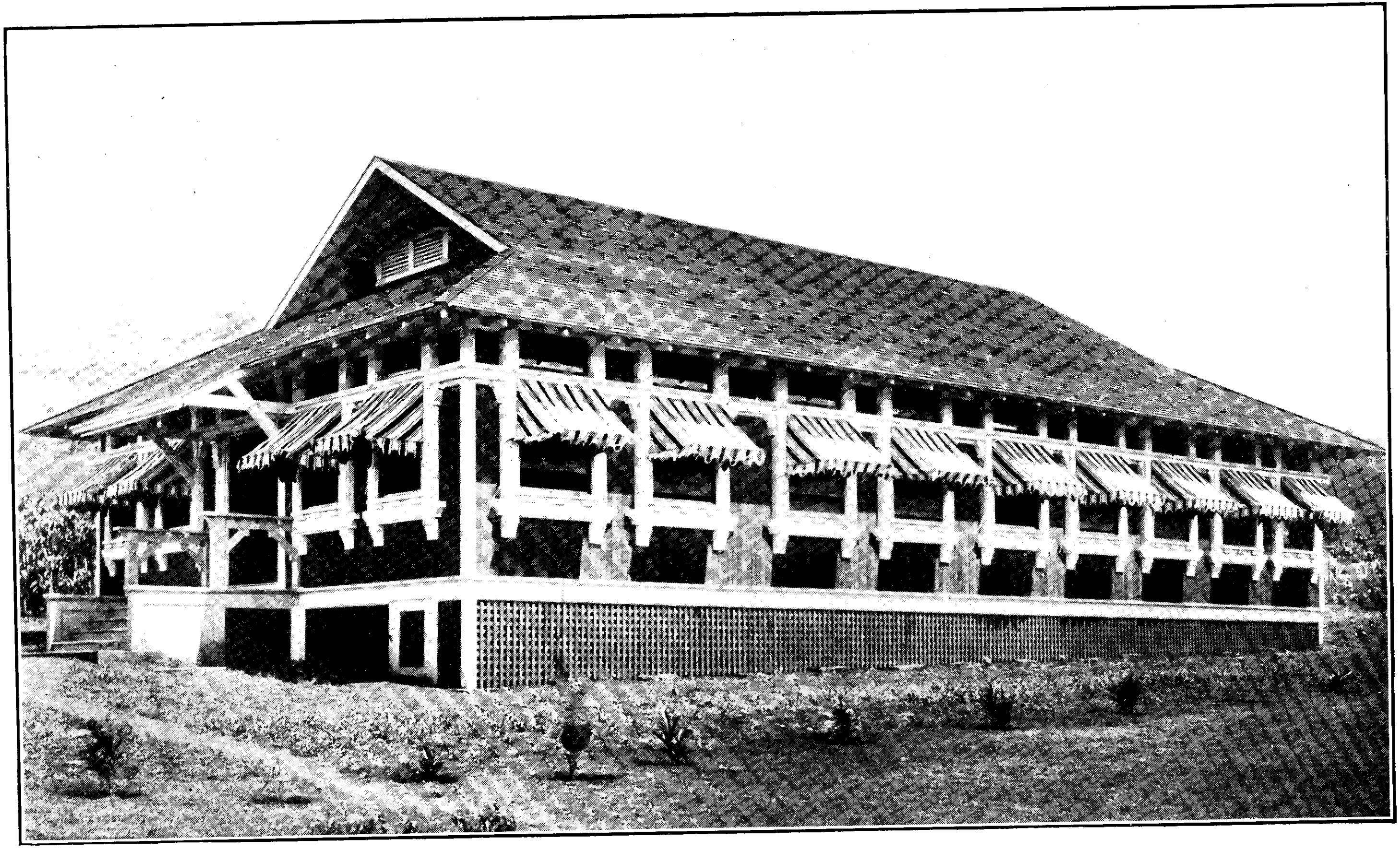

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, October 25, 1910.

SIR: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year 1910.

Respectfully,

E. V. WILCOX,
Special Agent in Charge.

Dr. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.

A. C. TRUE, *Director.*

Publication authorized.

JAMES WILSON, *Secretary of Agriculture.*

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ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1910.

SUMMARY OF INVESTIGATIONS.

By E. V. WILCOX, *Special Agent in Charge.*

BUILDINGS.

During the fiscal year ended June 30, 1910, a new office building (frontispiece) was erected from funds generously supplied by the Territory of Hawaii. The new building is better lighted than the old one; gives room for a more convenient library, and also offices for the special agent in charge, clerical force, entomologist, and agronomist, as well as for a mailing room. The chemical laboratory in the old cement building was inconvenient and has, therefore, been rearranged and new tables have been constructed for analytical and general work. A more efficient hood has also been devised for carrying off the fumes, and a new room arranged for nitrogen determinations.

GROUNDS.

Some of the land nearest Honolulu belonging to the experiment station has been heretofore in an uncultivated and unimproved condition. During the year this land was cleared and planted in Bermuda grass for lawn purposes or in various crops used in experiments. In addition, about 10 acres of land, lying on the slope of the station grounds, at an elevation of about 250 feet, has been thoroughly cleared of shrubby undergrowth and about one-half of it has been planted to cotton and other crops. The chief buildings belonging to the station are erected on grounds which heretofore belonged to the Navy Department and which were temporarily turned over to the use of the Agricultural Department. During the fiscal year this land was definitely transferred to the Department of Agriculture by an agreement reached between the Secretary of the Navy and the Secretary of Agriculture.

DEMONSTRATION FARMS.

It has been felt for some time that on account of the fact that the Territory consists of several islands, located at considerable distances apart, demonstration farms were desirable in order to bring the work of the station more prominently before the inhabitants of the other islands of the group as well as on Oahu. The problem of establishing demonstration farms in Hawaii is somewhat different from that which must be met in the States of the mainland. Farming communities are composed of different races, and a large proportion of the farmers who have small holdings are quite unacquainted with the purposes of demonstration farms. It appears, therefore, inadvisable to carry on such work according to the methods long in vogue on the mainland.

The objections to those methods, in so far as Hawaii is concerned, are chiefly two. Perhaps the more important is the matter of funds, which are at present inadequate to carry on demonstration farms on each of the islands independently of private help. The Territory has freely offered to turn over the necessary land to the station for such experiments, but the Territorial funds available for station use are not adequate for the maintenance of independent demonstration farms. There would be required a large outlay for fencing, buildings, machinery, horses or mules, foremen, and laborers. Such an arrangement would also result in the production of a considerable amount of material which would have to be sold in the open market. An objection has been made to this on the grounds that the station would, in a sense, be competing with practical farmers and with an unfair financial advantage.

The second objection to the mainland program of demonstration farms follows from the nature of the farming population in Hawaii. A community of Portuguese and native farmers can best be persuaded to adopt improved methods, actually shown to be advantageous, when these methods are put in operation upon farms belonging to one of the most progressive farmers in each community. It therefore seems best to establish demonstration farms essentially on the basis of a cooperative experiment. Several such farms will be put in operation during the fall of 1910. The program consists essentially in making an arrangement with one of the best farmers in each community to adopt certain modifications of cultural methods which the station will suggest and to keep careful record of the results of such work for the use of the station and all his fellow farmers. By this method it is believed that the results shown on the demonstration farms will be more readily accepted and will more obviously meet the exact conditions under which the farmer must labor.

COOPERATIVE EXPERIMENTS.

During the time which has been occupied in determining upon a practical method of carrying on demonstration farms, practically the plan outlined above has been put in operation on a number of large estates. The station has undertaken the supervision of certain cultural, soil, and fertilizer experiments on Molokai, Maui, Hawaii, and Oahu. The crops involved in these experiments are pineapples, cotton, rubber, corn, legumes, rice, sorghum, and a number of miscellaneous forage crops. These cooperative experiments have in all cases moved along very smoothly, for the reason that the private individuals concerned were intensely interested in bettering their cultural methods and establishing more extensive areas of cultivated crops, and also, for the reason that a highly intelligent and reliable control was exercised over the management of the experiments and the keeping of records. While cooperative experiments on the mainland and elsewhere, in many instances, cause considerable annoyance to both the station and the private individuals concerned, the cooperative experiments in Hawaii have been strikingly free from such troubles. So long, therefore, as the work can be carried on with relatively little interference with the time and energy of the station staff, it seems highly desirable to continue them where satisfactory arrangements can be made. It is a pleasant duty to acknowledge the active and intelligent interest which has everywhere been shown in the cooperative experiments thus far carried on by the station.

RATIONAL SOIL PROGRAM.

The soils of the Hawaiian Islands are very different in several respects from those which are familiar to farmers and agricultural workers on the mainland. In the first place, the Hawaiian soils contain high percentages of iron in various forms (say from 15 to 30 per cent). In addition to the high iron content, the soils contain more titanium than mainland soils, and in some localities, also a large amount (up to 9 per cent) of manganese. The presence of the large quantity of iron in Hawaiian soils gives them physical properties which are seldom met with in soils on the mainland. Wherever special attention is not given to cultivation, the soils rapidly become impervious to water and air and the iron present in the soil is reduced to the ferrous state. This, as is well known, is injurious to plant growth and is instrumental in preventing adequate aeration of the soil. Moreover, when the iron exists in the ferrous state and the soil can not be aerated, the use of fertilizers gives little or no benefit. It is therefore necessary to adopt a rational soil program, with the central idea that of securing a better aeration and better physical properties of the soil. Studies, which are designed to throw light on the practical methods of accomplishing such a result, are now in progress at the station, and the suggestions, already made by the station chemist, are being put into practice in a number of localities. It may be truthfully said that in many localities the chief soil problems are concerned with the physical rather than the chemical properties of the soil. Improper aeration not only causes the iron to become reduced to the ferrous state, but may also prevent the utilization by the plant of the plant food naturally present in the soils.

The study of cultural and rotation methods for securing a better aeration of the soil will be continued during the coming year, both in pot and field cultures.

RICE.

The chemical work on rice during the fiscal year was concerned chiefly with the study of the time or stage of growth at which fertilizers should be applied and the influence of various elements of plant food upon the composition of the rice plant. It was found during these experiments that the program adopted by the growers, in using fertilizers on rice, was somewhat ill advised, as judged by the physiology of the rice plant. It appears that the rice plant, by the time it is two-thirds grown, has already taken up about four-fifths of the nitrogen and phosphoric acid, and nine-tenths of the potash which will be absorbed during its whole growth; and that, therefore, fertilizers should preferably be applied before planting the rice, or, at any rate, during the very early stages. The value of nitrogen in rice culture has proved in the station experiments to be greater than was previously suspected. On some of the rice soils the use of phosphoric acid and potash gives no beneficial results. On these soils nitrogen alone produces as heavy yields as do complete fertilizers.

It was soon noted in experimenting with fertilizers on rice that nitrate of soda appeared to produce no beneficial effect, while ammonium sulphate was very active in promoting growth and yield of grain. This point has been carefully studied through two crops of rice at the trial grounds, and through several series of pot experiments. In almost every instance nitrate of soda gives no increase of growth over that observed in check plats or check pots; in fact, while it may be too early to conclude positively, the pot experiments thus far carried out indicate that the rice plant can not use nitrogen in the form of nitrate, but only in the form of ammonia. It had already been suspected by other investigators that ammonia was better than nitrate for rice, but it has hitherto never been shown that the rice can not use nitrogen in the form of nitrate.

The importation of rice from Japan continues to increase, and the production of rice in Hawaii has slightly decreased. In order to get further information on the cause of this condition, and to learn more in detail the methods of rice cultivation in Japan and the varieties used in that country, the agronomist visited Japan and China during the past year. It was found that the Japanese have a decided preference for certain varieties of rice which are almost the only kinds exported to Hawaii for use by the Japanese population, and that these varieties are claimed to have certain superior culinary qualities which can not be definitely described. Seed of about 150 varieties of rice was brought back from Japan, including a considerable quantity of seed of four of the best varieties grown in that country. These have been distributed to growers and reports regarding their behavior are expected during the coming year. A test of fertilizers on a commercial scale will be carried out for the purpose of demonstrating the results which have already been obtained at the trial grounds and in pot cultures. It is believed that these demonstrations will lead to a change of method in the application of fertilizers, resulting in greater economy and increased growth.

Experiments are also under way with a number of legumes and other crops, some of which were recently imported from Japan, to be used in rotation with rice in order to maintain the high yield which has hitherto prevailed in Hawaii.

COTTON.

Experiments with cotton were begun by the station three years ago and have yielded striking results in certain localities in which commercial plantings, to the extent of about 500 acres, have been made. During the coming year these plantings will be greatly increased. A number of points have been quite clearly demonstrated during these experiments. It has been shown that cotton will thrive under a wide range of rainfall—from 25 to 100 inches per year—and at a considerable variation of altitude, from sea level to 1,600 feet. The most favorable locations, however, are low-lying lands near the seashore and protected by algaroba, or other windbreaks, from the winds which occur during the winter. Although at elevations below 300 feet a temperature as low as 50° F. is very rare in Hawaii, nevertheless, at such a temperature cotton shows the effect in a marked degree. The leaves even may turn brown, as if they had been frosted. With regard to rainfall, a moderate amount per year is decidedly more favorable for the growth of cotton than a higher or lower rate of precipitation.

One difficulty which has been experienced in growing Sea Island cotton in Hawaii is that of excessive yield, which results in a too prostrate form of growth. In one locality on the windward side of Oahu, where the rainfall is about 70 inches per year, 2 acres of Sea Island cotton required about 5,000 props in order to keep the branches from lying upon the ground and causing the bolls to rot. In this respect the Caravonica cotton is superior to Sea Island, since it invariably has an upright habit of growth. The difficulty experienced with the prostrate habit of the Sea Island can be appreciated from a consideration of the fact that in the 2-acre field just mentioned and in another 1-acre field, on the leeward side of Oahu, the average number of bolls per plant was 700, and on one tree 1,200 bolls were counted at one time. This produces a weight under which the slender branches of the Sea Island can not support themselves in an upright position. An elaborate series of pruning experiments is now under way with the idea of learning a method by which an upright growth can be induced in the Sea Island cotton, at least for the second and subsequent years of the crop. Some promise is already held out by these experiments. A strain of Sea Island, secured from one of the best plantations on James Island, S. C., shows a more upright habit of growth than any other strain of Sea Island which has thus far been secured.

The Caravonica cotton continues to give promising results. During the first year of its growth the yield appears to be normally low, but in the second year a heavy yield is obtained, which, in conjunction with the greater ease of picking and the higher percentage of lint, makes a choice between Sea Island and Caravonica somewhat doubtful. Egyptian cotton has given results as satisfactory as those obtained with Sea Island. The strains of Egyptian cotton with which the station is experimenting grow rather more vigorously than the Sea Island, and the yield is perhaps slightly larger. The place which Egyptian cotton should take in the agriculture of Hawaii will largely be determined by the future demands of the market for the three chief types of cotton now grown in the Territory. In addition to Sea Island, Caravonica, and Egyptian cottons, experiments are being made with Chinese upland, a number of varieties of upland from the Southern States, and a cotton with red lint, from Cuba. It is proposed to make a reciprocal cross between Sea Island and Kidney cottons in order to determine whether Caravonica cotton was originated in this manner and whether an improvement upon the ordinary type of Caravonica can thus be secured. Several plants have been found in different localities in the Territory where a natural cross between a pure Sea Island and a pure Kidney cotton could have taken place, and these plants strikingly resemble, in habit of growth and quality of lint, the ordinary type of Caravonica cotton.

It has been found that pure strains can be propagated by means of cotton cuttings, and a number of cuttings will come into bearing during the present season. In addition to this method of propagation budding has been tried on a large scale. Propagation is an easy matter by the method of budding, but the economy of the method on a commercial scale has not yet been determined. According to the present outlook it seems an economic proposition to bud over large areas with bud wood from the best plants, and thus secure a uniform cotton over the whole field. This method would, of course, have no value except where cotton is cultivated as a perennial crop.

PINEAPPLES.

In connection with the study of manganese in the soil as affecting the growth of pineapples, experiments have been made with a number of crops which could possibly be grown in rotation with pineapples or to replace pineapples in the manganiferous soils. For this purpose corn, rice, and various other cereals, tobacco, cotton, legumes, garden vegetables, and fruit trees were used. It has been found that manganese invariably causes a yellowing of all the leaves and a premature falling of the lower leaves on all plants with which experiments have been made. The plants may subsequently become green, just before the fruiting period, at which time a vigorous growth may be observed for a short period. The ultimate outcome, however, is in all instances a decidedly stunted growth and small yield. The root system in manganiferous soils is peculiar in the length and fineness of the small roots. The ultimate outcome in pot experiments is a root system strikingly different from that in ordinary garden soils. Apparently the extreme fineness of the roots is due to the lack of resistance which they meet in penetrating manganiferous soils. These soils invariably remain loose like ashes, no matter how frequently or heavily they may be irrigated.

In the fertilizer experiments with pineapples, which are being continued by the chemist, it has been found that phosphates, particularly acid and reverted phosphates, have a beneficial effect upon the growth of the pineapple plants, probably for the reason that these materials tend to render the manganiferous salts in the soil less soluble. Lime, on the other hand, is decidedly injurious on manganiferous soils, as shown by the experiments of the station and by tests which have been tried by growers on a commercial scale. The injurious effect of lime is possibly due to the fact that it helps to furnish conditions favorable for the formation of the higher oxids of manganese, which are the most injurious salts of this mineral.

A study of the ripening of pineapples has disclosed the fact that the sugar content of the fruit is derived exclusively from the leaves of the plant and does not increase after the fruit has been removed from the plant. If pineapples are picked green and allowed to ripen the sugar content at complete ripeness is the same as it was when the fruit was removed from the plants. An analysis of the fruit shows that they contain no substance which can be changed into sugar during the ripening process. Fruits picked too green and allowed to ripen, therefore, lack greatly in sugar content and in flavor. The sugar content of green fruits, or fruits ripened after being picked too green, is about 2 or 3 per cent, while that of fruits ripened on the plant ranges from 9 to 15 per cent. The ripening process in fruits picked green appears to consist largely in a softening of the tissues. A microscopic examination of sections of green pineapples shows that the cell walls in the parenchyma of the fruit are greatly thickened, but become extremely thin in ripening. It is obvious from these facts that in order to obtain a good flavor in fresh fruit the fruit should not be picked until the sugar content has become fairly high and the fruits have turned yellow to the extent of about one-fourth their length at the base.

HORTICULTURAL INVESTIGATIONS.

Satisfactory progress has been made in propagating avocados, especially by budding. The method reported in the last annual report has been put into operation on other trees, and the results thus far obtained are very promising. A number of difficulties, particularly the drying of the bud, have been successfully overcome.

Attention has been given to the varieties of avocados to be found in the Territory. There appear to be quite a number of recognizable varieties, but most of them have not been definitely named. Four varieties of special merit have received attention on account of their being especially adapted to shipping, extra late, extra early, or of exceptional quality.

Similarly with mangoes, the methods of propagation reported in the last report and in Bulletin 20 of this station, have continued to give good results. In one case fruit was borne upon a graft within eighteen months after insertion. Continued tests of the possibility of transplanting mango trees have shown that this operation is relatively simple and successful in the majority of cases. The insect pests and fungus diseases of avocados and mangoes have not proved to be especially serious when proper treatments are applied.

A large collection of papaya seed was made from trees in various localities whose fruit was reported to be of special value or of excellent flavor. From the observations made on papayas there seem to be two distinct types (diœcious and monœcious), in Hawaii, with various intermediate forms. The diœcious type occasionally has a fruit borne among the staminate flowers. The monœcious type of papaya bears fruit on every tree. The monœcious type has both perfect and staminate flowers on the same tree and is the one which lends itself best to breeding and selection. As long as the diœcious type is used one must depend upon cross-fertilization, and the characters can not be fixed as readily as where close fertilization can be carried on. Moreover, when the diœcious type is used, a certain percentage of trees will prove to be males, and therefore sterile. A large amount of space in the orchards is thus lost, as well as the time which has been expended in cultivating the male trees. There is considerable evidence that ultimately a strain of papayas will be produced which will come true to seed. Since seed is the only apparent practical means of propagating papayas, it seems wise to make every possible effort to obtain seed with fixed characters.

It was considered desirable to learn the state of the market in San Francisco for sweet potatoes during the season when sweet potatoes are not to be had in that city from local sources. For this purpose two shipments were made from the station, with the result that all varieties, of whatever color, if of standard size, were accepted at 8 cents per pound in San Francisco. The market price of sweet potatoes in Honolulu is usually from 70 cents to $1 per hundred. It would be, therefore, obviously a good practice to make at least one planting of sweet potatoes for the purpose of shipment to California sometime during the interval between the first of May and the middle of July.

ENTOMOLOGICAL INVESTIGATIONS.

During the year the attention of the entomologist was directed to a number of miscellaneous insect outbreaks, to the insects of the sweet potato, and certain enemies of forage crops, and to the propagation of parasites, particularly for the algaroba bean weevil. A bulletin on sweet potato insects has been prepared and will be issued during the coming year. Considerable time has been spent in studying the insect enemies of corn, and it is proposed to take up a study of the chief pests of the principal forage crops in Hawaii as occasion may offer.

More than 2,000 parasites of bean weevils, obtained through the Bureau of Entomology of the United States Department of Agriculture, in mesquite pods, were reared at the station and turned out at various points on Oahu, Maui, and Molokai. The result of this importation of parasites is not yet apparent, but one egg parasite appears to have become quite effective during the past season.

RUBBER.

Opportunity was had during the year to visit all of the commercial rubber plantings of the Territory. These are located on the windward side of Maui and in the Puna district of Hawaii. A satisfactory growth is manifested everywhere in the rubber plantations between the lowest altitudes and an elevation of 1,400 feet. No commercial plantings have been made at higher elevations. On all of the plantations Ceara rubber grows much more rapidly than Hevea rubber. The latter does not make as rapid growth in Hawaii as it is reported to make in the Straits Settlements and Ceylon. The question whether Hevea should be extensively planted in Hawaii seems to depend on whether the ultimate yield will be enough larger than that of Ceara to counterbalance the long waiting period for the first tapping.

Wherever clean cultivation has been adopted, the growth of the trees is incomparably more rapid than where no cultivation has been practiced. Trees which have received clean cultivation since planting are larger at 2 years of age than 6-year-old trees which have not been cultivated. The necessity of cultivation is apparently, for the most part, due to the lack of aeration and the presence of stagnant water in the soil. As soon as cultivation is begun the soils allow the passage of water much more freely and drainage is decidedly better.

Where the rocky nature of the soil will not permit cultivation, it is necessary to destroy the weeds by other means, and a comparative experiment has been made to determine the effectiveness of sulphate of iron and arsenite of soda as herbicides. The cost of spraying with arsenite of soda is a little less than with sulphate of iron, and its effectiveness appears to be greater. About 500 acres of land in the rubber plantations have been sprayed with arsenite of soda. This land is of a rough nature and is covered with both shrubby and herbaceous weeds of a great variety. From one to three applications of arsenite of soda are required to clean the land of all vegetation. Even lantana and other shrubby plants are killed down to the ground by the spray. The total cost for material and labor ranges from $1.25 to $2 per acre; the expense, is, therefore, much less than that incurred by hand or horse implements. Arsenite of soda has also been used at the station on a number of weeds, including Japanese nut grass, which is probably the worst weed in cultivated land in the Territory of Hawaii. This weed is killed down to the ground by a single application of either arsenite of soda or sulphate of iron. It sprouts up again after a considerable interval, but the young plants are weak and may be destroyed by a second application.

TARO.

There are lands in the Territory which are known to have been cultivated almost continuously to taro for several hundred years. The station has made an arrangement to carry on a fertilizer test on a taro plantation which has been continuously in this crop for 200 years. In some fields of the plantation a decided diminution in yield has been noticed. On account of the active interest which the plantation managers take in the matter, this is believed to be a particularly favorable opportunity to learn the fertilizer requirements of taro and to compare them with conditions met in rice culture under water.

BROOM CORN.

A considerable quantity of broom-corn seed was distributed to growers in different parts of the Territory, and about 1 acre was planted on the station grounds. The seed was planted rather late, and the crop was, therefore, attacked by plant lice to a most unusual extent. The growth of uninfested plants was quite satisfactory, and heads of normal size are now forming. If the cultivation of broom corn proves to be a paying line of farming, it is proposed to build a broom factory in Honolulu for the local trade.

REPORT OF THE ENTOMOLOGIST.

By D. T. Fullaway.

GENERAL NOTES.

During the year the usual insects were noticed attacking agricultural crops. Some recently introduced pests have increased to an alarming extent and exemplify the destructiveness of harmful insects in the absence of natural enemies. Outbreaks of cutworms and army worms occurred in many localities during the winter, causing severe losses. The rice crop was not affected this year, but several wheat fields were devastated. The corn leaf aphis contributed to the destruction of the wheat and barley crops. In the fall pineapple plants on the Consolidated Pineapple Co.'s plantation were badly damaged by an introduced locustid, *Xiphidium varipenne.* The insect attacked the leaves of the pineapple, making large abrasions which permitted the entrance of fungus hyphæ, causing the leaves to wilt and die back. This feeding habit is very extraordinary for the insect, which usually feeds on pollen. The eggs of the locustid are much parasitized, so that it is not likely to become a serious pest of pineapples. The injury, in fact, has not continued. The edible nuts of the litchi tree in several Honolulu gardens were badly attacked in July by a tortricid moth, *Cryptophlebia illepida.* The larvæ bore into the succulent fruit and render it unfit for use. On the trees of one private orchard practically the entire crop was destroyed. An attempt was made the present year to prevent this loss by spraying, but the crop of nuts was small, and the moth did not appear to be very troublesome, although it was present as usual in klu and koa pods.

Some attention was given to bee keeping, but nothing done in the way of investigation. It is a pleasure to record that this minor industry is now well established here. The bee keepers are progressive, and the industry is growing. One corporation keeping bees has gone extensively into queen rearing, and during the last year several Japanese and Australian apiaries were supplied with queens from these islands. No new bee plants were introduced, but the better of those already secured were rather freely distributed.

Numerous inquiries which were received during the year in regard to insect pests and remedies for them were answered by correspondence. In some cases personal inspection of the conditions was made and advice offered. The station's collection of economic insects was maintained and much material added. New office rooms and much new and better equipment were secured.

While matters of immediate concern received due attention, the work of the entomologist was, as far as possible, confined to definite lines of investigation. This kind of work is believed to be more progressive and permanent than scattered efforts with an immediate object in view.

ALGAROBA WEEVIL PARASITES.

At the beginning of the year shipments of bean weevil parasites were received through the cooperation of the Bureau of Entomology, United States Department of Agriculture, and much time was given to taking care of the material, securing the parasites, and releasing them. Later a search was made to find if they had become established, but this could not be verified except in the case of the minute egg parasite (Trichogramminæ), which bred freely from the eggs of bean weevils on beans brought in from the field. The following is a detailed report of this attempted introduction:

Lot 1 (June). One box of pods of the mesquite, infested with *Bruchus prosopis* and *B. amicus*, from Dr. F. H. Chittenden. Parasites obtained from this lot were all *Heterospilus* sp.

Lot 2 (July). Three boxes of mesquite beans containing *B. prosopis* and *B. amicus*, from Mr. W. D. Hunter. Parasites obtained were *Heterospilus* sp. and *Urosigalphus bruchiphagus*.

Lot 3 (August). One large box containing 30 pounds of mesquite beans with *B. prosopis* and *B. amicus*, from Mr. W. D. Hunter. Parasites obtained were *Heterospilus* sp., *Urosigalphus bruchiphagus*, *Eurytoma tylodermatis*, and Trichogrammid.

Lot 4 (August). Two boxes containing *B. prosopis* and *B. amicus*, from Mr. W. D. Hunter. Parasites obtained principally *Heterospilus* sp.

Lot 5 (September). Two boxes containing *B. prosopis* and *B. amicus*, from Mr. W. D. Hunter. Parasites obtained were *Heterospilus* sp. and *Urosigalphus bruchiphagus*.

Lot 6 (September). One large box containing 30 pounds of mesquite beans with *B. prosopis* and *B. amicus*. Parasites obtained were *Heterospilus* sp., *Urosigalphus bruchiphagus*, *Eurytoma tylodermatis*, *Cerambycobius cushmani*, and Trichogrammid.

All attempts to breed the parasites in confinement failed. The parasite house, which offered the only secure place for breeding work, was too dry and hot. In the breeding house it was necessary to place the material in breeding jars and there the beans molded. Under the circumstances it was necessary to liberate the parasites at once and allow them to take their chances in the field. On advice, only

Heterospilus sp. was released, and in all 2,303 were liberated—a fair proportion being males, with which the females had been confined from five to ten days before liberation. This parasite has not been seen since. The parasites were mostly liberated on the grounds of the experiment station. One lot of 250 specimens was released on the Alexander and Baldwin plantation at Puunene, Maui; another lot of 200 on the Isenberg ranch at Waialae, Oahu; and another lot of 100 on the Molokai ranch near Kaunakakai. Attempts to breed *Eurytoma tylodermatis*, of which probably 50 were obtained, in confinement were unsuccessful.

INSECTS OF FIELD CROPS.

Considerable time was given during the winter to the investigation of the insects affecting field crops. The greatest hindrance to the diversification of agriculture in these islands has been the ravages of insects, and numerous attempts to grow cereals and the ordinary field crops have ended in failure, owing to sudden and severe attacks of insect pests which have been half-heartedly and unsuccessfully coped with. The object of the investigation was to learn what insects attack field crops and their method of attack, in order to suggest means of combating them successfuly. An excellent opportunity was offered to begin this kind of a study in the 200-acre experiment at Kunia, on this island. The locality in which the Kunia Development Co.'s operations are being conducted is typical of much of the land that is available for diversified farming. It was new land, without water, and close to the mountains. All the elements of chance in diversified farming were present. The results of the first year's cultivation suggested plainly that success or nonsuccess depends largely on whether or not effective measures are adopted to suppress insect pests and are applied with thoroughness.

The crops under observation were corn, wheat, barley, oats, jack beans, and cotton.

CORN.

The following insects were observed to attack corn:

Cutworms (*Agrotis ypsilon* and *A. crinigera*).[1]
Army worm (*Cirphis unipuncta*).[1]
Grass army worm (*Spodoptera mauritia*).[1]
Looper (*Plusia chalcites*).
Angoumois grain moth (*Sitotroga cerealella*).[2]
Corn leaf aphis (*Aphis maidis*).[3]
Corn leafhopper (*Peregrinus maidis*).
Rice weevil (*Calandra oryza*).

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[1] Hawaiian Sugar Planters' Sta., Div. Ent. Bul. 7, 1909.

[2] Hawaiian Planters' Record, 2 (1910), No. 2, p. 102.

[3] Hawaii Sta. Rpt. 1909.

Wireworm (*Simodactylus cinnamomeus*).
Tenebrionid beetle (*Epitragus diremptus*).
Cryptoblabes aliena.[1]
Batrachedra rileyi.[1]
Amorbia emigratella.[2]
Opatrum serratum.
Adoretus tenuimaculatus.
Aræcerus fasciculatus.
Plodia interpunctella.
Ephestia elutella.
Setamorpha sp. (Reared by Swezey.)
Catorama mexicana. (Reared by Swezey.)
Nitidulid. (Reared by Swezey.)

WHEAT.

The following insects were observed attacking wheat:
Cutworm (*Agrotis crinigera*).[3]
Army worm (*Cirphis unipuncta*).[3]
Grass army worm (*Spodoptera mauritia*).[3]
Looper (*Plusia chalcites*).
Leaf roller (*Omiodes localis*).[4]
Corn leaf aphis (*Aphis maidis*).[5]
Opatrum serratum.
Epitragus diremptus.
Wireworm (*Simodactylus cinnamomeus*).

BARLEY.

The following insect was observed on barley:
Corn leaf aphis (*Aphis maidis*).[5]

JACK BEAN.

The following insects were observed on the jack bean:
Grass army worm (*Spodoptera mauritia*).[3]
Leaf miner (*Agromyza* sp.).

COTTON.[6]

The following insects were observed attacking cotton:
Cutworm (*Agrotis crinigera*).[3]
Grass army worm (*Spodoptera mauritia*).[3]
Cotton aphis (*Aphis gossypii*).[5]

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[1] Hawaiian Sugar Planters' Sta., Div. Ent. Bul. 6, 1909.
[2] Hawaii Sta. Bul. 22, 1910.
[3] Hawaiian Sugar Planters' Sta., Div. Ent. Bul. 7, 1909.
[4] Hawaiian Sugar Planters' Sta., Div. Ent. Bul. 5, 1907.
[5] Hawaii Sta. Rpt. 1909.
[6] Hawaii Sta. Bul. 18, 1909.

Many of these pests are discussed in technical papers, in which life histories, remedies, natural enemies, etc., are given. References to these papers are made opposite the name of the insect. The following notes of observations at Kunia in connection with these crops are offered:

Cutworms and army worms undoubtedly did the most damage to the corn. Plants several weeks old in sections of the fields were so badly eaten that replanting became necessary. In other sections plants were literally stripped, both stalk and ear. The lower leaves were badly frayed and skeletonized by *Plusia chalcites* and the young larvæ of *Spodoptera mauritia*, but this injury is negligible. The corn leafhopper and corn leaf aphis are at times very injurious, especially to young plants. The ripening ears were attacked by *Cryptoblabes aliena*, *Amorbia emigratella*, and *Batrachedra rileyi*, which work in the silk at the flower end, also eating some of the cob. These insects attacking the standing corn are to be expected and can and ought to be systematically fought. For cutworms and army worms, the use of light traps in addition to poison bait is suggested. It might also be profitable to spray or dust the plants once or twice with arsenate of lead. The aphis and leafhopper may be sprayed with tobacco decoction, but they are difficult to control artificially.

The insects which attack matured ears or stored corn, such as the Angoumois grain moth, corn seed weevil, etc., can be best controlled by fumigating the stored corn. Corn stored in a tight bin may be fumigated with carbon bisulphid, 1 pound to 1,000 cubic feet; if the storeroom is not tight, the dose should be doubled.

Cutworms, army worms, and corn leaf aphis did the greatest damage to the wheat and barley, and in order to grow these grains it seems essential to control these pests in some way. The remedies suggested above are the only practical ones that can now be recommended, but the present situation might be greatly altered by the introduction of good parasites for this class of pests.

The dipterous leaf miner infesting jack beans gave this crop a very ragged appearance, and in sections the plants were eaten down to the ground by the army worm. The leaf miner is parasitized and is troublesome only at times. The army worm can be controlled with the remedies mentioned above.

The cotton aphis and climbing cutworms did the most damage to the cotton during the winter. The aphis was particularly bad, becoming so abundant as to cover both stems and foliage, and killing some plants. It is difficult to control by artificial means, but a spray of kerosene emulsion or tobacco decoction might be beneficial. Climbing cutworms should be fought with poisoned bait or by spraying with arsenate of lead.

In the spring the insects attacking the sweet potato were studied. The sweet potato is extensively cultivated here and is a staple article of food, especially among the Hawaiians and poorer classes. It has a number of insect enemies which damage the crop more or less, but do not prevent fair yields. The study was made as complete as possible within the limited time, life histories were obtained for most of the pests, and remedies elaborated. The results are now in manuscript and will later appear as a bulletin.

The most destructive pest of sweet potatoes apparently is the stem borer (*Omphisa anastomosalis*), a recent introduction from China. It bores into the stems and kills many plants. It sometimes gets into the potato, in which case the damage is even more serious. It is not much parasitized and is quite common in sweet-potato fields. It would be difficult to control artificially. The leaves of the sweet potato are mined by the larvæ of the tineid moth (*Bedellia orchilella*), and probably by other species of this genus, but this pest is fairly well kept in check by chalcid parasites. The hornworm (larva of the sphinx moth, *Phlegethontius convoluli*) is quite common but not often very injurious; cutworms are said to attack the sweet potato; and there are two leaf rollers (*Phlyctænia despecta* and *Amorbia emigratella*) which damage the foliage to some extent. The common sweet-potato weevil (*Cylas formicarius*) has at times been a very destructive pest and one difficult to control. It breeds in the stems of the common shore plant (*Ipomœa pes-capræ*), and will always be a menace to the cultivation of sweet potatoes, although actual instances of its infesting sweet-potato fields are few. Another weevil, the West Indian scarabee (*Cryptorynchus batatæ*), is also common in the tuber or rootstock of the sweet potato and at times greatly damages the crop. Among the minor pests may be mentioned the leaf hoppers *Nesosydne ipomœicola* and *Oloha ipomœa*, *Plusia chalcites*, an undetermined Pseudococcus, the Japanese beetle, and a species of Saissetia.

Considerable time has been spent in studying Coccidæ—a group of extreme economic importance in these islands—but no report can be offered on this work. An addition was made to the list of Hawaiian Coccidæ in recording the presence of *Geococcus radicum* Green on roots of mango, koa, and nut grass. The insect was described and figured anew by the writer.[1]

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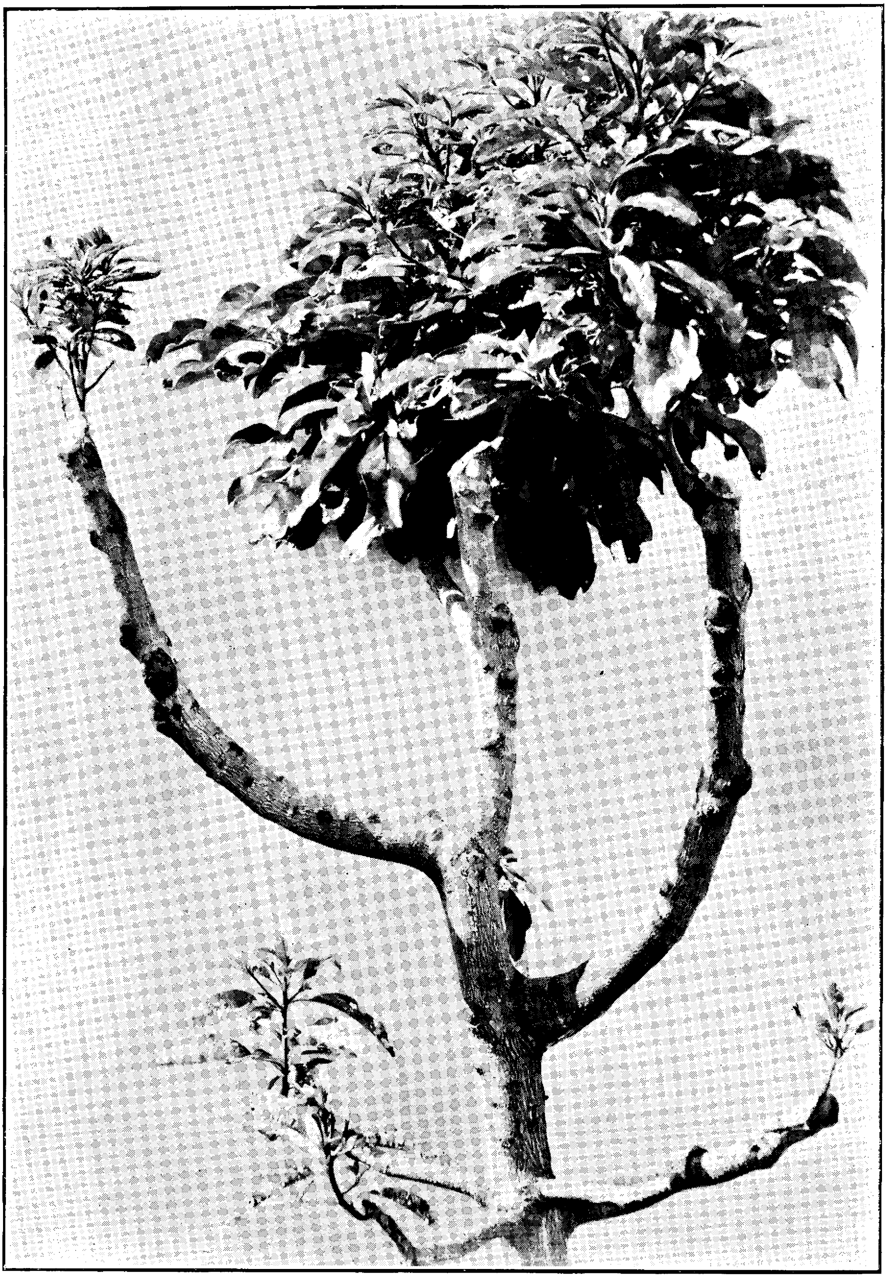
[1] Proc. Hawaiian Ent. Soc., 2 (1910), No. 3, p. 108.



A FIVE-YEAR-OLD AVOCADO TREE, TOP WORKED TO A SELECTED VARIETY BY BUDDING.

REPORT OF THE HORTICULTURIST.

By J. E. Higgins.

The work of this department for the fiscal year dealt chiefly with the avocado, mango, papaya, and citrus fruits. Minor attention has been given to the sweet potato and to a considerable number of miscellaneous subjects which demand recognition in the present stage of Hawaii's horticultural development.

AVOCADO.

The work with avocados during the year may be classified chiefly under four subjects, as follows: Propagation, insect control, disease control, and study of varieties.

PROPAGATION.

Substantial progress has been made in devising means for the successful budding of the avocado. Because of the lack of young nursery stock most of the trials have been in topworking of orchard trees. Plate I shows a tree in the experimental orchard topworked to a valuable variety by means of budding.

The greatest difficulty in budding appears to be not in getting the buds to unite with the stock, but in forcing them into growth. The sap of the avocado oozes out from incisions in the bark, and in budding this characteristic aggravates the difficulties. The sap finds an exit through the T incision, evaporates, and leaves here a crystalline deposit which frequently covers the whole bud, and sometimes the whole bud shield. This is particularly likely to occur before a union has been effected, although it may occur long after. It has been found possible largely to control this trouble, during the period when union is being effected, by wrapping the whole of the stock, in the region of the incision, and thus preventing evaporation.

When a bud has become united to the stock it has proved inadvisable to lop the stock immediately, as is done with citrus and some other budded stocks. The wood is often so brittle in the young portion, where the bud is inserted, as to prohibit successful lopping. If partly cut, it will snap off completely. If a stock is completely cut off, it is likely to die back to the bud and below it before the latter has started into growth.

To overcome these difficulties it has been found advisable to girdle the stock completely, or partly, at a point several inches above the bud, being careful to remove only the bark, so that the upper portion will not be destroyed. Mr. Holt, who has done most of the actual manipulation of the buds under the direction of the horticulturist is continuing the work with a view of overcoming more completely some of the difficulties which have made the budding of avocados somewhat discouraging.

Inarching is being successfully used for certain types of propagation. It is quite easy to effect a union of scion and stock by this method, which presents a very ready means of bringing seedling varieties into early bearing by placing them on old trees. This may prove to be one of the best means of testing out seedlings whose characters it may be desired to determine, either for practical or scientific purposes.

Some success has been had in growing avocados from cuttings. It has frequently been found in the station experience that avocado cuttings readily form a callus, but do not strike root. The method which has proved partly successful in causing the formation of roots during the past winter consists in packing the cuttings in moist sphagnum moss for several weeks before placing them in the propagating bench. Thus far well-matured wood with gray bark has proved most promising in this work. If cuttings can be made to root readily there are occasions when this means of propagation could be advantageously used.

INSECT CONTROL.

The two chief insect pests of the avocado in the station orchards during the year have been the avocado mealy bug (*Pseudococcus nipæ*) and the larva of the tortricid moth (*Amorbia emigratella*). The latter has caused considerable damage to foliage in the station orchard and to the fruit in gardens of the city. The larva wraps itself up in the young leaves, sometimes sewing together the terminal leaves while opening. It inhabits this place until the food supply is somewhat reduced and then proceeds to another similar locality. Because its attack is upon the very newest growth it is not as easy to control by arsenical poisons as would otherwise be the case. However, frequent spraying with arsenate of lead has considerably reduced the numbers of these insects.

The avocado mealy bug for some years has not required much attention to keep it under control in the station orchard. Practically no spraying has been done for two or three years, and only an occasional tree has been fumigated. There are always some insects of this species in the orchard, but they do not appear to become a serious pest, probably being held in control by ladybirds. It is aimed to foster these by planting, every rainy season, a cover crop of cowpeas, jack beans, or some similar legume, which is subject to the attacks of aphides. These aphides do not disturb the avocado, but multiply in the legumes and furnish an abundant food supply for numerous species of ladybirds. After this food supply has been cut off, these natural enemies of the mealy bug turn their exclusive attention to the scale insects of the trees.

DISEASE CONTROL.

A fungus disease of the avocado, probably a species of Glœosporium, has done much damage in many parts of the Territory; in fact, no district has been visited by the horticulturist in which this disease has not been very prevalent. It attacks the leaves, causing them to become a rusty brown color, and frequently causing them to fall prematurely. It also causes the dying back of the twigs and branches and often results in the total destruction of the tree. During the past season, flowers were noticed destroyed apparently by this fungus, the destruction extending into the new wood. When the vitality of the wood has been reduced, it becomes an attractive place for borers.

Work has been begun to test the efficiency of four leading fungicides in the control of this disease. With these fungicides, arsenical poisons have been included, when possible, as a means of destroying the Amorbia mentioned above. The remedies being tried are: Bordeaux mixture with arsenate of lead (6–6–50 formula); resin lime mixture with Bordeaux (formula, 2 gallons resin lime stock to 48 gallons Bordeaux dilute); self-boiled lime-sulphur wash (6–6–50 formula) with arsenate of lead; and commercial lime-sulphur (formula 1–30), with arsenate of lead. It is too early to look for marked results from the use of these fungicides, since the work has been in progress only a short time. It can be said, however, that none of the remedies has produced any serious foliage injury.

VARIETIES.

Mr. Hunn, the assistant horticulturist, has made careful studies of a large number of varieties of avocados for the purpose of ascertaining their merits for commercial or home production. Many very excellent midseason varieties have been found. These, unfortunately, are not the best adapted to commercial growing, because they would reach the mainland when the markets were overstocked with many kinds of Temperate Zone and subtropical fruits. There is, however, a sale for such in limited quantities at high prices even at that season. First-class avocados in sound market condition will sell at that season of the year (June, July, and August) at $2 to $2.50 per dozen in the San Francisco market. The extra early varieties, which could be placed in mainland markets before the 1st of

June, and the extra late varieties which would be marketable after the 1st of November, could be sold in large quantities, as the demand for fresh fruit is better at that time. The four varieties following are of particular merit from one or another of the points of view indicated above:

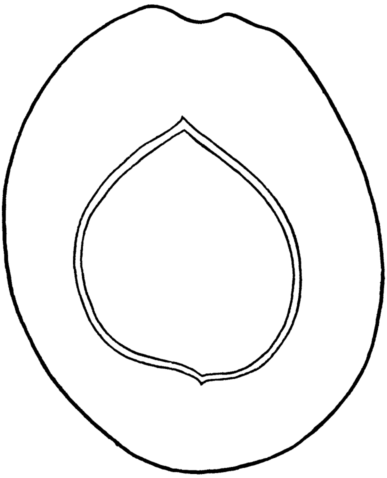


FIG. 1.—Form of fruit and seed of avocado No. 149. About one-fourth natural size.

No. 149 (Fig. 1). About 20 years ago Admiral Beardsley, leaving Guatemala for Hawaii, carried with him a number of avocados for consumption on the way. He saved two seeds, wrapping them in cotton wool and packing them in ice. Arriving in Honolulu, he gave one seed to Judge Wiedeman and the other to Mrs. E. K. Wilder. The former was planted at 1402 Punahou Street, now occupied by "The McDonald," and although both seeds grew, this one is far superior in quality and blooms earlier.

Form roundish to spherical; size medium to medium large; cavity small, shallow, and flaring; stem somewhat slender and very long, varying from 6 to 15 inches in length; surface undulating, very hard; coriaceous and markedly pitted; color dark olive green to purple, with small, very abundant, irregular-shaped yellowish dots; apex a mere dot, slightly depressed; skin very thick and woody, separating freely from the pulp; flesh yellow in color, running into green at the skin, fine grained, oily and somewhat buttery, 75 per cent of fruit; seed fairly large, roundish conical, just a trifle loose in the cavity; flavor rich and nutty. Season July to January.

The tree is quite vigorous, but tends to grow upward rather than to branch out, probably due to confinement. This pear is especially noteworthy, since it will keep for a long time after being removed from the tree. Mr. G. P. Wilder reports that he has kept the fruit for two and one-half weeks after removal from the tree. The tree carried fruit over through the blossoming period of the following season. Height 40 feet, spread 20 feet.

Valuable as a late avocado. Its woody skin should make it a good shipper.

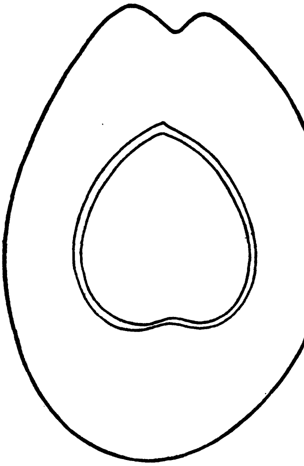


FIG. 2.—Form of fruit and seed of Moanalua avocado. About one-fourth natural size.

MOANALUA (Fig. 2). A chance seedling 19 years of age growing on the estate of Hon. S. M. Damon, Moanalua.

Form pyriform; size small to medium; cavity flaring, deep; stem somewhat short, rather thick; surface undulating, hard, coriaceous, and slightly pitted; color dark green, with medium abundant, small, irregular-shaped yellowish dots; apex a mere dot; skin medium thick, separating readily from the pulp; flesh yellowish in color, running into green at the rind, fine grained, melting and somewhat buttery, 70 per cent of the fruit; seed medium large, conical, fitting tightly in the seed cavity; flavor rich and nutty. Season July to September.

The tree is very vigorous. Height 30 feet, spread 25 feet.

No. 150 (Fig. 3). A chance seedling whose origin and age are unknown, growing near the residence of Charles Renear, Emma Street.

Form pyriform; size small to medium; cavity shallow and somewhat rounded; stem short and medium thick; surface undulating, medium hard, coriaceous, slightly pitted; color green, with reticulate-like markings, with medium large somewhat circular yellowish dots; apex a mere dot; skin very thin, separating readily from the pulp; flesh yellow, melting, but a trifle watery, 70 per cent of the fruit; seed medium large, conical, fitting loosely into the cavity; flavor pleasant. Season middle of May to July.

Valuable because of its earliness. Height 30 feet, spread 20 feet.

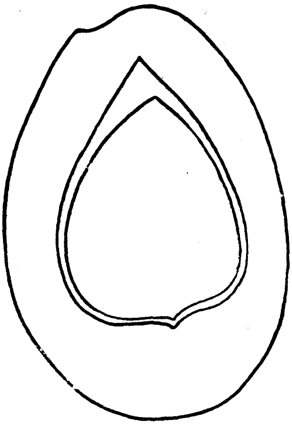


FIG. 3.—Form of fruit and seed of avocado No. 150. About one-fourth natural size.

No. 145 (Fig. 4). A chance seedling about 15 years of age; origin unknown.

Form pyriform; size small to medium; cavity shallow and somewhat abrupt; stem medium long and quite thick; surface undulating, hard, coriaceous, and slightly pitted and mottled; color green, with small, very abundant yellowish dots; apex a depressed dot; skin quite thin, separating fairly well from the pulp; flesh yellow, running into green at the rind, fine grained, oily, and somewhat buttery, 60 per cent of the fruit; seed very large, conical, fitting loosely in the cavity; flavor rich and nutty. Season September to January.

This tree is very vigorous and symmetrical. Height 25 feet, spread 25 feet.

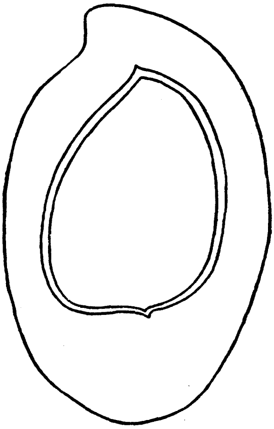


FIG. 4.—Form of fruit and seed of avocado No. 145. About one-fourth natural size.

FERTILIZER TRIALS.

The station orchard, consisting of miscellaneous varieties and many seedlings, makes it impossible to conduct an exact fertilizer experiment, but certain sections of the orchard have been chosen which apparently furnish sufficiently uniform conditions for some simple trials of fertilizers. It is hoped that these tests, conducted in cooperation with the chemical division of the station, will point the way to more definite and accurate experiments when uniform conditions can be attained. From our observations there is some evidence that the excessive use of nitrogenous fertilizers may tend to produce a fibrous fruit.

MISCELLANEOUS STUDIES.

Some studies have been made of the root system of the avocado. Attention has also been devoted to pruning, girdling, and other orchard operations.

MANGO.

PROPAGATION.

The propagation work with the mango has been continued along the lines outlined in previous reports and bulletins. Good use has been made of the method of shield budding the mango.[1] By this means a still larger number of new varieties have been worked in the trial orchard. Quite a number of potted trees have been taken to the orchard and have afforded inarches on some of the older seedling trees. A marked example of the results which may be obtained by this method has come into the station experience during the year. In December, 1908, an Indian variety, Brindabani, was thus grafted upon a strong seedling in the orchard. At the present writing, 18 months later, the new variety is bearing fruits nearly fully matured, others in various stages of development, and also flowers.

TRANSPLANTING.

Opportunity has been afforded for still further testing the possibilities of transplanting large nursery trees. Quite a number of 4 and 5 year old trees were taken up from the nursery and removed to the orchard, in part to test this matter, since it has frequently been stated that mango trees are difficult to transplant. All the trees were severely cut back, leaving only a trunk about 2½ feet above the crown. The transplanting was done in the autumn and early winter, at a time when the trees were not flushing. Some of the trees were removed with naked roots and carefully taken at once to the orchard. Others were taken out with a ball of soil and planted immediately. Still another lot, which had been dug up 15 days previously and had been carefully "heeled in," were planted beside the others. A fourth lot, which had been treated in the same manner as lot 3 except that the naked roots were exposed to the air for an hour or two, was also planted. It has not been possible to detect any difference in the vigor of growth of any of the above lots, all trees having lived and made a good growth.

Mr. E. C. Smith, of Pearl City, Oahu, reports that he at one time removed a mango tree which had been bearing, and though severely cut back even the next year's crop was not lost. It appears, therefore, that if mango trees are transplanted when not in flush and are severely cut back a large degree of success can be expected in transplanting.

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[1] Hawaii Sta. Bul. 20.

The above results of trials, together with the methods of budding the mango referred to, would seem to place beyond doubt the growing of the mango as nursery stock on a commercial scale

ROOT SYSTEM.

Studies have been made of the root system of the mango by sluicing away the soil and removing the tree with its main roots intact.

INSECT CONTROL.

It has been found necessary to fumigate a few trees in the mango orchard for the destruction of the scale (*Phenacaspis eugeniæ*) and also a few for the Florida red scale (*Chrysomphalus aonidum*). When the mango tree is not flushing it can be fumigated with hydrocyanic-acid gas in doses equal to those used on citrus trees without injury to the foliage.

A red-banded thrips (*Heliothrips rubrocinctus*) should be mentioned in this connection. These were found in large numbers on young mango seedlings in the greenhouse, and were causing very serious damage. They were referred to the station entomologist, who kindly had them identified as above. Those who are starting mango plants in greenhouses or in a sheltered place should be on the lookout for these pests. They may be distinguished as small, rather wedge-shaped bodies, very beautifully marked with red bands. It has not been found difficult to destroy them by dusting the plants with finely powdered sulphur after they have first been sprayed with water so as to retain the powder.

The species of Amorbia referred to elsewhere as a pest of the avocado has also proved destructive to the mango flowers and to some degree to the young leaves. Arsenate of lead has been found effective in destroying the larvæ.

The large carpenter bee (*Xylocopa æneipennis*) did considerable damage to young mango buds in the propagation experiments until its work was discovered and prevented. The bee seems to find an inviting place for boring just above the bud on the bud shield, and in many instances bored through the shield into the old wood of the stock, causing injury and sometimes destruction to the bud. It has been found easy to control this injury by placing grafting wax in all the incisions, leaving only the bud and a small portion of the shield exposed. This should be done when the bandage is removed, if injury of this kind is experienced.

DISEASE CONTROL.

The fungus (*Glœosporium mangiferæ*) does great injury to the mango crop in Hawaii, destroying the flowers and much of the fruit. It has been stated in earlier reports that this disease can be held in control by Bordeaux mixture. Experiments, however, have been undertaken with other fungicides for the control of this fungus. The same series of trials, as outlined elsewhere for the control of the diseases of the avocado, is in progress in the mango orchard.

VARIETIES.

There is now quite a large number of varieties in the station orchard. Some of these are introduced varieties from India and elsewhere, and others are valuable local seedlings. The list of varieties now growing at the station is as follows:

Alphonse, Accession Nos. 1072, 1158, 2014, 2101.
Douglas Bennett's Alphonse, Accession Nos. 278, 1161, 1370, 1371, 1926, 1933.
Ameeri, Accession No. 2100.
Arbuthnot, Accession No. 1943.
Bombay Yellow, Accession Nos. 1029, 1921.
Brindabani, Accession Nos. 1202, 1372.
Cambodiana, or Saigon, Accession No. 260.
Crescent, Accession Nos. 1945, 1946, 1948.
Divine, Accession No. 2108.
D'Or, Accession No. 2109.
Cowasjee Patel, Accession No. 2485.
Faizan, Accession No. 1200.
Fijri Long, Accession No. 1920.
French, Accession Nos. 1962, 1963.
Gay, Accession No. 1940.
Herbert's No. 9, Accession Nos. 1960, 1967, 1968.
Jamshedi, Accession Nos. 1201, 1373.
Java, Accession Nos. 1949, 1950, 1953.
Julie, Accession No. 2102.
Lady Finger Chutney, Accession No. 1271.
Mazagon, Accession No. 2484.
Mulgoba, Accession No. 2093.
Paheri, Accession No. 2094.
Peters No. 1, Accession No. 2092.
Pirie, Accession No. 1159.
Sharhati Black, Accession No. 1203.
Strawberry, Accession No. 1533 (local seedling).
Strawberry, Accession No. 1944 (from Section of Seed and Plant Introduction).

Sandersha, Accession No. 1074.
Totafari, Accession No. 279.
Smith Wootten, Accession No. 1985.
Wootten Chutney, Accession No. 840.

PAPAYAS.

MONŒCIOUS AND DIŒCIOUS TYPES.

Investigations have been begun with papayas which are of interest because of their bearing upon theories of plant breeding and also because of their practical aspect. It is a well-known fact that papayas are extremely uncertain in the reproduction of their characters. Selection has been practiced to a considerable degree by the growers of this fruit, but seeds from the best fruit are liable to produce trees of very indifferent character. The reasons for this may be suggested by a study of the different types of the papaya. There are two extreme types and several intermediate forms. First, there is the strictly diœcious type. In this, the fruit-bearing tree produces pistillate flowers only. The staminate, or "male," tree produces staminate flowers almost exclusively but with an occasional perfect flower which is capable of producing fruit. Most of the staminate flowers have a rudimentary ovary and style, but are without any stigma, and are utterly incapable of fruit production. The fruit of the pistillate tree of this type is usually ovoid or more or less rotund in shape.

The second type is monœcious. Every tree produces fruit. The trees produce two forms of flowers; first, a perfect flower, and, second, a staminate flower. In the axil of each leaf there is usually a small flower cluster, only a few inches in length, which contains at least one perfect flower and one or more staminate ones. This perfect flower is quite different in shape from the pistillate flower of the diœcious type. Its pistil is much more elongated, being almost cylindrical throughout a portion of its length. The stamens are usually situated on the inner walls of the petals, about midway of their length, with the anthers surrounding the lobes of the stigma. The fruit of this type differs from the fruit of the diœcious tree in the same way as the pistils. The fruit of this monœcious type is usually elongated, and is generally spoken of as the "long" papaya.

Between these two types, the one almost completely diœcious and the other monœcious, there are many intermediate forms which may have arisen through the crossing of these two. For example, there are in the station collection trees which produce three types of flowers, namely, staminate flowers and two forms of perfect flowers. The one form of perfect flower corresponds precisely with the perfect flowers of the monœcious type, spoken of above. The other perfect flower has an ovary in shape like that of the pistillate flower of the diœcious type, and produces a fruit more nearly resembling this type. Its stamens, however, are variously located; they may be found at times arising from the base of the petals; or at times the anthers are attached to the lobes of the ovary, the latter condition usually resulting in a deeply furrowed or distorted fruit. One tree in the station collection produces only staminate flowers, but is peculiar in the fact that these flowers are borne close to the stem and in the axils of the leaves, while staminate trees of the ordinary diœcious type produce their flowers in long pendant clusters.

BREEDING PROBLEMS.

What is the bearing of these facts to a practical plant breeder who may wish to produce a papaya of a good variety whose characters will be more or less stable in reproduction? Suppose that the diœcious type is used in selection, as has been the case usually. Seed from this fruit will necessarily be a cross of two individuals. The characters of the female plant are known, but those of the male plant are utterly unknown. The parent stock from which both came may be known, but since there is wide variation in the fruit of two pistillate trees from the same stock it is reasonable to suppose that there will be the same wide variation in the male or staminate trees. The variation between the pistillate trees can easily be determined because their fruits are in evidence and can be tested; but the characters which are inherent in the male or staminate tree, and which will be transmitted by it to its progeny, can be determined only through the long process of actual hand-pollination, the sowing of the seed thus produced, and the testing of the fruit. Even then, what portion of its excellent or indifferent qualities it may have inherited from its male parent can not be known. Furthermore, the difficulty becomes aggravated by the fact that papaya trees usually degenerate after a very few years. At least, pistillate trees usually fail to produce good fruit after a few years of growth, although they may continue to produce indifferent fruit for many years. Therefore, even if the inherent characters of the male or staminate tree could be determined with reasonable accuracy, before any such determination could be made the tree would have become too old to be in a reliable state of virility, if it degenerates as rapidly as the pistillate tree. It therefore appears reasonable to suppose that the process of producing a stable variety of good qualities by the use of this diœcious type would be extremely long and tedious. The hope, therefore, must lie in the use of the monœcious type. Here it is possible to select an individual of known qualities. This may be used as the sole parent stock, or may be combined with another parent of known qualities. Of course, either may at the start be of uncertain reproducing power. That is to say, what mixtures of blood there may be in the individual at the start may not be known; but through repeated selections and the elimination of undesirable characters, it should be possible to produce a reasonably stable variety, provided, of course, that the stock is kept pure by constantly avoiding cross-pollinations, a process which is necessary in all plants reproduced by seed and whose flowers are subject to accidental cross-pollination.

A further practical difficulty in the use of the diœcious type, from the standpoint of the papaya grower, as well as the breeder, is the fact that a very large proportion of the trees from any given lot of seed are liable to be staminate, or males, and therefore useless, only a few trees being necessary to pollinate all the pistillate trees. It is impossible to distinguish the staminate from the pistillate trees in the early stages of their development. Various theories have been advanced to distinguish these two sexes before the trees have flowered, and it has been reported that staminate trees have been caused to produce pistils and fruits by beheading them. None of these means, however, has proved to be successful from a practical standpoint. Therefore, in any papaya orchard planted with the diœcious type, a very large percentage of the trees must be cut out after they have grown almost to maturity, resulting in unevenness and irregularity in the orchard and much loss of time and space. For this reason, together with the difficulties of breeding, the diœcious type will likely be largely eliminated.

Returning to the subject of papaya breeding, it is not yet known what the result will be from crossing the pistillate tree of the diœcious type with pollen from a tree of known character of the monœcious type. As has been indicated above, there are several intermediate forms which appear to be the result of crossing the monœcious and the diœcious types; but, apparently, there is no definite knowledge on this point. These intermediates may have resulted from the accidental crossing of the monœcious type with pollen from the staminate tree of the diœcious type. It may be possible to make some of these crosses without giving rise to an undue number of male or staminate trees.

This work which is only in its incipiency offers a wide and interesting field for investigation.

CITRUS FRUITS.

INSECT CONTROL.

No new problems have been undertaken with citrus fruits. The orchard is being maintained and has afforded opportunity for the further testing of fumigation with hydrocyanic-acid gas for the control of the mealy bug (*Pseudococcus filamentosus*) and other scale insects. This method of control has proved the most effective means which has yet been tried. It is extremely difficult to control *P. filamentosus* because it is so vigilantly attended by ants. It has been found possible to destroy the insects on the trees by fumigation if the soil is removed from the crown so as to expose the insects to the gas. Reinfestation, however, takes place more rapidly than in the case of the Florida red scale (*Chrysomphalus aonidum*) and the purple scale (*Lepidosaphes beckii*).

The caterpillar (*Amorbia emigratella*), referred to as a pest of mango and avocado, has required considerable attention. After consultation with the entomologist, treatment was begun with arsenate of lead. Because of the habit of this insect, in wrapping itself up in the newest growth, it becomes difficult to poison it with arsenical sprays. The spraying was repeated several times. The insect now appears to be fairly well under control.

NEW VARIETIES.

Several new varieties of oranges, pomelos, and lemons have been introduced during the year. A number of the newer Florida pomelos have been budded into the station orchards and nurseries. The station agronomist, Mr. F. G. Krauss, while traveling in Japan and China, collected some of the best pomelos of those countries, including the famous Amoy variety. Bud wood was brought back to Hawaii, and some of it arrived in fair condition. Buds were inserted in a number of stocks at the station, but none has succeeded. The buds " took," and a few started into growth but afterwards failed.

A number of citrus varieties have been received from Mr. Gerrit P. Wilder while traveling through the Orient and southern Europe. These have been worked into the nursery by both budding and grafting and are making good progress.

SWEET POTATOES.

In a bulletin of this station,[1] attention was called to the possibility of a profitable industry in the shipping of sweet potatoes from Hawaii to the mainland of the United States and Canada during the season when the market there is practically bare, because the home-grown product is out of season. All these markets are accustomed to the yellow variety, known on the Pacific coast as Merced Sweet. This local name has arisen from the fact that Merced is the center of the most successful sweet-potato cultivation. The variety is that usually known in the East as the Jersey Sweet. It was also stated in the bulletin referred to that the red varieties commonly grown in Hawaii are unfamiliar to those markets. This left the question open as to whether Hawaiian sweet potatoes of the ordinary varieties would find a ready sale on the mainland.

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[1] Hawaii Sta. Bul. 14.

This matter has been tested by the growing of a number of varieties and the marketing of the same in San Francisco. The first two shipments included several red sorts as well as the Merced. All varieties sold readily at 8 cents per pound. Later reports, however, brought out the fact that the dealers found the consumers prejudiced against the red color and refused to buy them. It would seem to be unwise for Hawaiian shippers to attempt to break down this prejudice, and attention should be given to the growing of the Merced variety, with which the market is familiar. Roots of this variety are being distributed by the station.

These trial shipments confirm the earlier belief that sweet potatoes of suitable varieties will bring high prices when the California product is out of season.

It seems hardly necessary to state that 8 cents per pound should not be expected on large shipments. The commission house which handled these trial lots advised the station as follows:

"If you can succeed in producing the yellow variety of medium to large size, we are confident they can be distributed here during our late spring and early summer season so as to make them quite profitable to you. By this we mean from 4 cents to 5 cents per pound with a possibility of higher prices for a portion of them."

The season of shipping is important. California sweet potatoes are out of season from about May 15 to August 1. This is the period during which Hawaiian-grown sweet potatoes should arrive. In some years it may be found possible to put them in a little earlier.

MISCELLANEOUS NOTES.

Quite a large amount of miscellaneous work presents itself from time to time, and miscellaneous plants of different species demand some attention. A few of these may be mentioned.

GARCINIA MANGOSTANA.

The mangosteen has one or two bearing trees to represent it in Hawaii. Two fruits, which represented half the crop of one of these trees, were secured a year or two ago. One of the two fruits contained a seed, which was planted and has made rather an indifferent growth, but has done better than plants which have been introduced in Wardian cases.

There are one or two other species of Garcinia in Hawaii which appear to do well. It has seemed probable that the mangosteen might do better in Hawaii if budded on other stocks. Mr. E. W.

Jordan secured bud wood of the mangosteen from Mr. Francis Gay, of Kauai, and the writer, in cooperation with Mr. Jordan, placed buds of these on the *Garcinia xanthochymus*, known locally as the "African mangosteen." This work was performed only a few weeks previous to the present writing, and it is therefore too early to know whether any successful results will arise.

CARISSA ARDUINA.

Carissa arduina (Ac. No. 1764, S. P. I. No. 11734), which is a South African fruiting shrub, was introduced from the Section of Seed and Plant Introduction of the Department of Agriculture in the year 1905 under the number indicated above. The four plants received at that time have all made a vigorous growth, but have exhibited decided differences in character. Two of the plants have proved heavy producers and two have been rather shy bearers. Plate II, figure 1, shows one of these trees in fruit.

The shrub is useful as a hedge plant because of its dense growth and its strong thorns, which render it practically impassable, and also for its very beautiful red fruits, which are about the size of a plum. The latter may be eaten from the hand or may be used in the manufacture of jellies.

Selections are being made of the best fruits from the two best trees. About 2,000 plants are now in the greenhouses and will be ready for distribution within a few months. There remains a large crop of fruit, affording the opportunity for still larger propagation and distribution. It is believed that the plant will be useful as a hedge to surround fruit gardens which are subject to the attacks of nocturnal visitors.

After the plants have become well established in the propagating houses they appear to be free from all serious insect attacks in Hawaii. They are subject to the attacks of the scale, *Saissetia hemisphaerica;* but this is so successfully parasitized in Hawaii by *Scutellista cyanea* and other parasites that it has not proved a pest on Carissa.

LITCHI (NEPHELIUM LITCHI).

A number of the plants of this species, introduced from China in 1908, have made a fair growth, although severely attacked by the Japanese beetle and by the scale (*Saissetia nigra*). The latter can readily be controlled by fumigation, and it is not believed that the Japanese beetle will prove a serious pest after the trees have grown to large size. The seedling litchis that are growing in various parts of Honolulu are not seriously attacked by this pest.

The litchi, being a slow grower and requiring usually from 15 to 20 years to come into bearing, when grown from seed in Hawaii, it

PLATE II.

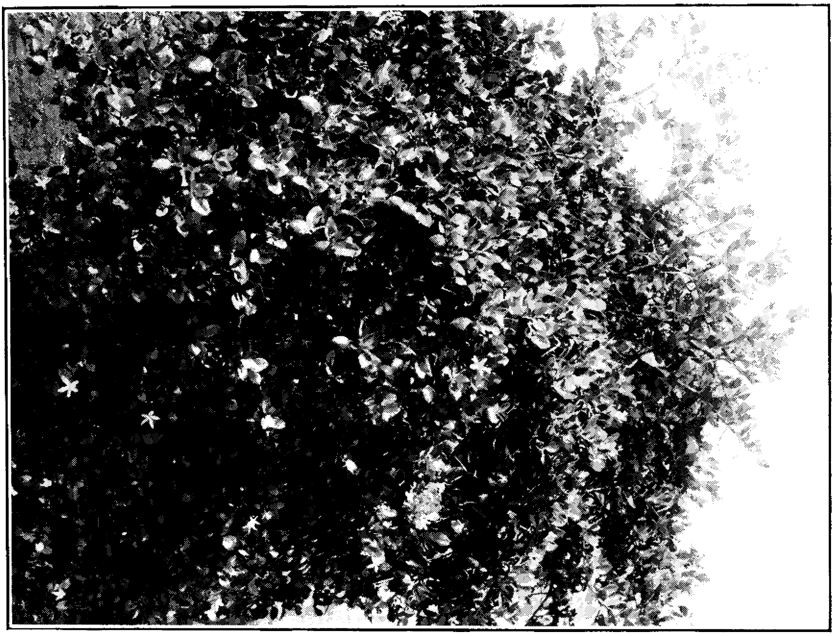

FIG. 1.—CARISSA ARDUINA, A VALUABLE FRUIT AND HEDGE PLANT.

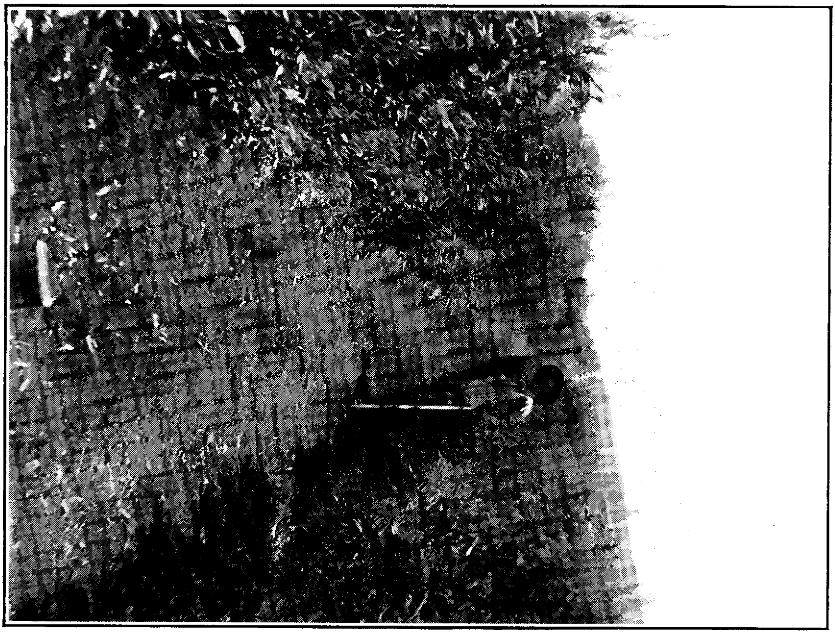

FIG. 2.—PIGEON PEAS AS A WINDBREAK FOR NURSERY STOCK.

has been thought desirable to attempt the growth of this tree on the more vigorous growing stock of the longan (*Nephelium longana*). Attempts are now being made to graft scions of these imported varieties on seedling longans by the inarching method.

DECIDUOUS FRUITS.

As stated in previous reports, the Parker ranch has undertaken rather extensive experiments in the growing of deciduous fruits and grapes. In these experiments the station has taken a considerable interest and has cooperated so far as possible. In February, 1910, the horticulturist again visited the chief of these plantings at Waiki, on the island of Hawaii, at an elevation of about 4,500 feet. Instruction was given in pruning, insect control, and the general care of the orchards, and observation was made of the progress of the different kinds of fruits being grown. This being the winter season, it was impossible to judge of the fruits themselves, except in the case of a few apples which had been kept through the winter. These were of good size, and those that were not withered by exposure to the air were crisp and of good flavor. Apples have made a very satisfactory growth, except those planted the previous season, which was one of unusual drought. Established trees seemed to do well, notwithstanding the prolonged dry weather. Peach trees also made a satisfactory showing and were reported to have produced good fruit. They were well supplied with fruit buds. Cherries have not succeeded, and plums and pears can not yet be said to have proved a success. Grapes of several varieties, including the Tokay and the Muscat, have made good growth and are reported to have produced fruit in 1909. In general, it may be said that the outlook is promising for the production of apples, peaches, and grapes in this locality.

TREE TANGLEFOOT.

This sticky substance has been used on the deciduous plantings, as well as on the station trees, for the purpose of preventing ants, cutworms, and other injurious insects from ascending the trees. Under some conditions it has proved quite effective if the surface is kept renewed by repeated agitations, or combings. A serious result appears to have followed the use of this remedy at the Waiki orchards on peach trees. It had been applied directly to the bark of the trunk and had remained for many months. Wherever it was found remaining upon the peach trees they were dead. Examination of the bark of the trunk under this sticky preparation revealed injury of the tissue and a discoloration which extended completely around the trunk. This remedy has been applied to the bark of a number of trees at the experiment station without any apparent injurious effects, but it has not been so applied to peach trees. It is, therefore, recommended that precaution be taken in its use, and that in the case of peach trees, particularly, it should not be applied directly to the bark. A broad bandage, made of cheap cotton dipped in hot paraffin, may be wound spirally around the trunk of the tree and tied at the top by splitting into two parts like a surgeon's bandage. To this the sticky substance may be applied without injury. If the cotton is not too strong there will be little danger of girdling.

PIGEON PEA.

The pigeon pea (*Cajanus indicus*) is being tested as a temporary wind-break and as a permanent wind-break for nursery stock. In two or three months from seed, it affords considerable protection to small growth, and in six or seven months attains a height of 6 feet, and thus makes a good wind-break for young citrus, avocado, and mango seedlings. For this purpose it is planted quite close in the row, the plants standing only 3 or 4 inches apart. In citrus nurseries, the rows of these fruit trees are being tried at 6 feet apart, and a row of pigeon pea is being planted midway between the citrus. Where land is cheap, it would be better to increase the distance between the rows. By this means the wind-break could remain as long as the trees might be in the nursery. Plate II, figure 2, shows the pigeon pea protecting young citrus seedlings.

RATTAN PALMS.

Several species of this palm, Dæmonorops, have been introduced from Java. About 200 of these palms have been distributed in different parts of Hawaii where it was thought they would be most likely to succeed. These plants afford a fiber which is used in the shipping of tobacco, and if successful in Hawaii should be a valuable aid to the tobacco industry.

BOUGAINVILLÆA DISEASE.

A disease of the bougainvillæa has been observed during the year on both the species *B. spectabilis* and the species *B. refulgens*. This is a sort of crown rot which causes the decay of the bark and wood near the ground. A large vine of *B. spectabilis* was treated by the removal of the dead bark and the washing of the wound with carbolic acid and water, after which paint was applied. The plant appears to be regaining vigor.

REPORT OF THE CHEMIST.

By W. P. Kelley.

During the past year the chemical department has been engaged mainly in soil and fertilizer investigations along the lines suggested in the previous report. In addition, some attention has been given to a study of the composition of pineapples.

PINEAPPLE SOIL INVESTIGATIONS.

In the report for 1909 the writer pointed out some of the conditions that exist in the pineapple districts of Oahu and drew attention to their peculiarities. Investigations during the past year have further emphasized the necessity of a more intelligent management of these soils. Frequent requests by farmers for assistance and advice, together with numerous observations by the writer, have led to the conviction that the time has already arrived when special efforts must be put forth by the farmer if profitable yields of pineapples are to be maintained. The pineapple industry, important as it has become, is still in its infancy in Hawaii, and while continuing to hold out great promise, failure, or only partial success, has resulted in numerous instances. This fact, together with the scientific interest that naturally arises in connection with soils of such abnormal characteristics, justifies a thorough study of all the factors that influence the ultimate fertility of this land.

In numerous instances the application of various fertilizers in liberal quantities has not given satisfactory returns, and an increasing number of planters are realizing that something more than the addition of available plant food is demanded in their fields. The lack of drainage is evident, and in many instances a poor mechanical soil condition is apparent. With satisfactory yields on virgin soil the growers in many instances have failed to adequately appreciate the importance of maintaining what is called "condition" in the soil. In the main the land is under short-term lease, and the principal idea from the beginning of this industry has been to get out of the land a maximum crop at a minimum of cost, with little concern for the ultimate maintenance of the soil.

The work of this department in this connection has been directed along lines which are calculated to show the fallacies of the prevailing system and to secure a scientific basis for rational and permanent conservation of the soil. Looking to this end a series of field and laboratory investigations are under way which have already resulted in data of scientific interest and of practical value, and when completed ought to enable the farmer to adjust his farm management so as to secure both profit from his efforts and a perpetuation of his business.

It is not considered necessary at this time to detail these investigations, as it is hoped to present this work in its entirety later in the year. The work is being directed toward a study of the effects of aeration, and the chemical and physical changes induced by continued cultivation are being studied in a systematic way. The nitrifying power of the soils, the decomposition of humus, and the physical and biological changes which develop at remarkable rates under the conditions that prevail are being given due consideration.

On Oahu, as previously pointed out,[1] the pineapple soils may be roughly classified as manganiferous and nonmanganiferous. The former, on account of their extreme abnormality, have received considerable attention. The extent of the black manganiferous soil is considerably greater than had been anticipated, and comprises an important part of the pineapple sections of this island. While the areas that contain 4 or more per cent of manganese are ill suited to pineapple growth, the results already obtained indicate that the areas which contain an intermediate percentage of this element may, by the use of suitable fertilizers, be cultivated in pineapples with fair success. The physical properties of the manganiferous soils are superior to those of the nonmanganiferous areas, and drainage is much better on these areas. Consequently if the toxic effects of manganese can be overcome, their cultivation in pineapples will be more permanent.

In one of the manganiferous fields a fertilizer test has been under way for sometime, and while some of the plants made fairly normal growth during their first year's development, with the return of winter and its incident low temperatures the pineapples became yellow and abnormal. Some of the plants, however, have partially regained a normal appearance during the warm weather of the past few months, and are now in full fruit. The plants treated with dried blood or ammonium sulphate, superphosphate or reverted phosphate, and sulphate of potash have from the first greatly exceeded all others, and while the yields will not be entirely satisfactory it suggests a possible treatment for soils that contain more limited quantities of manganese. This soil appears to be greatly benefited by the application of soluble phosphates,[2] although the chemical analysis shows that it contains a rather high percentage of this substance. Not all forms of phosphates, however, are effective. Basic slag produces an increased tendency to a yellowing of the plants, and usually results in poorer yields than no treatment.

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[1] Hawaii Sta. Press Bul. 23.

[2] See Agr. Gaz. N. S. Wales, 21 (1910), No. 5, pp. 437, 438.

The popular idea concerning the black manganiferous soils has been that they are sour and therefore in need of lime, but chemical analysis has proven this view to be incorrect, and the application of lime to these soils almost universally results in the development of a more intense yellow color in the plant and its subsequent failure to produce fruit. Basic slag is known to contain free lime, and it is likely that its injurious effect may be traceable to this substance.

A thorough study of the solubility of manganese and the influence of fertilizing substances on its solubility, the form in which the manganese exists in the soil and its relation to pineapple failure, and the influence brought about by the growth of pineapples on the form of the manganese in the soil, the influence of manganese on nitrification, and the physiological functions produced by this substance in the pineapple plant have received considerable attention.

Other crops have been grown on this type of soil in pot cultures with varying degrees of success. Some of these showed abnormal appearances, especially during the first two months of growth. Cereals seem especially sensitive to an excess of manganese. Legumes, although showing normal root tubercles, grew poorly. The lower leaves turned brown and fell away. Cotton and root crops seem less sensitive to this substance than other plants. In practically all plants grown in this type of soil peculiar color appearances were developed, indicating that it reacts in some way on the chlorophyll. In some instances the chlorophyll is destroyed; in others, etiolin or xanthophyll are developed instead of the green coloring matter.

These experiments will be repeated during the coming year and other crops tried and a further study of the physiological functions performed by manganese will be made.

In connection with the pineapple soil investigations on Oahu, some attention has been devoted to a study of the soils in pineapple sections of Maui, where different soil and climatic conditions prevail. Also, soil samples from Kula, the Parker ranch on Hawaii, and the Nahiku rubber district have been examined and some interesting results obtained.

RICE INVESTIGATIONS.

The fertilizer experiments with rice have been continued and some remarkably concordant results obtained. On account of the unreliability of a single year's test with fertilizers, the results of these experiments have not been published. It is customary with the Chinese rice growers in the islands to cultivate the same land in two crops of rice per annum, and where fertilizers are used generally only one application per annum, and that to the spring crop, is made. With the view of determining the residual effects on the fall crop from the spring application, the original plats in our experiments have been divided into two parts, one of which received an application to the spring crop only, the other the same application to both crops. These experiments have now been carried through three crops and preparations are now under way for the fourth. It is intended to make this a continuous fertilizer experiment, with the view of determining whether it is possible by the use of fertilizers to obtain satisfactory yields under continuous cultivation of rice. A rotation experiment, involving the use of fertilizers, is also being made. In addition, a series of plats, to which different forms of nitrogenous fertilizers were applied, was laid out and some very interesting results obtained. Some experiments[1] were made previously, which indicated that ammonium sulphate is the most economical form of nitrogen for rice culture. A duplication of these results has been obtained. The yields from the plats treated with nitrate of soda have consistently fallen far short of the yields obtained from the use of ammonium sulphate. This observation has led to a detailed investigation of the absorption of nitrogen by the rice plant.

In pot cultures, under strict chemical control, various forms of nitrogen have been applied and some remarkably interesting results obtained. Where the rice has access to nitrates, only very poor growth has resulted; whereas ammonium compounds have resulted in vigorous development. These experiments are being repeated and will likely form the basis for a publication later in the year.

The original practice of applying fertilizers when the rice is about two-thirds grown gave rise to a study of the absorption of nutrients by the rice plant at its several stages of growth. This investigation was carried through two crops with concordant results, and the complete data bearing on this subject have been published.[2] From the results obtained it would seem that the practice of late applications of fertilizers should be abandoned. A large percentage of the substances absorbed from the soil is taken up by the rice plant during its early growth, and greater economy is sure to follow the application of fertilizers before planting than can be obtained from making the applications at the time usually practiced. In connection with this investigation it has been shown that the composition of the rice plant may be materially affected by the application of soluble fertilizers: especially is this fact noticeable during the early development of the plant.

FERTILIZER EXPERIMENTS WITH COTTON AND RUBBER.

As announced in the previous report, two fertilizer experiments have been made with cotton. These are being continued with promising results. The yields of the first crop were, in some instances, more than three times as great on some of the fertilized plats as on the checks, and the appearance of the cotton at present indicates a similar influence in the second crop. The upland soils of the islands for the most part are lacking in available phosphates, due largely to the insoluble nature of the soil phosphates. Some attention has been given to a study of the solubility of phosphates in different types of soils,[1] and the results thus far obtained indicate that the phosphoric acid of the soil is largely combined with iron and alumina as basic phosphates, and hence insoluble.

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[1] Hawaii Sta. Rpt. 1907, p. 83.

[2] Hawaii Sta. Bul. 21.

A fertilizer experiment with rubber was also begun, but sufficient time has not elapsed to draw conclusions regarding the effects. Fertilizer experiments previously made with this crop were limited in number and no extensive results have been published. The slow growth of latex-bearing plants suggests the importance of a practical means of hastening the time of commercial tapping. In this experiment not only the increased growth of the trees is being measured, but the rate of latex flow and the percentage of rubber obtained therefrom will be noted. The soil on which this experiment is located is rich in humus, but inadequately aerated, as is shown by the fact that practically all the iron compounds therein are in a ferrous state, which can not be considered desirable at least. An increase in aeration, due to cultivation, has already been shown to produce an enormous increase in the growth of the rubber trees, and it is hoped at a later time to make a systematic study of this point.

THE COMPOSITION OF PINEAPPLES.

The composition of pineapples grown in other localities has been pointed out by several investigators. In a study of pineapples from Florida, the West Indies, Bahama, and Singapore, Munson and Tolman[2] showed that neither the variety nor the locality in which the fruit is grown exercises any marked influence on its sugar content, although the ratio between reducing sugars and sucrose in a given variety was shown to vary considerably. One pineapple of the Smooth Cayenne variety, for instance, was found to contain 3.17 per cent reducing sugars (calculated as invert sugar) and 7.51 per cent sucrose, while another of the same variety contained 9.75 per cent reducing sugars (calculated as invert sugar) and only 2.98 per cent sucrose. Some analyses were recorded which showed abnormally low percentages of sugar. This fruit was shipped a considerable distance before being analyzed, and irregularities in composition, as pointed out by the authors, may, in part, be traceable to differences in the degree of ripeness at the time of gathering.

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[1] Jour. Indus. and Engin. Chem., 2 (1910), No. 6, p. 277.

[2] U. S. Dept. Agr., Bur. Chem. Bul. 87, pp. 31–38; Jour. Amer. Chem. Soc., 25 (1903), No. 3, pp. 272–280.

Recently Blair and Wilson[1] made an extensive study of the composition of pineapples as affected by the use of fertilizers, and pointed out some interesting results. No extensive investigation of the composition of Hawaiian pineapples, however, has been published, although this fruit is generally conceded to be superior in quality to that grown in most localities.

The Smooth Cayenne is almost the only variety grown in Hawaii, and on account of inadequate shipping facilities and the prevalence of certain fungi a large percentage of these pineapples are used for canning purposes. The fruit for canning is allowed to ripen thoroughly in the field; that used for fresh fruit shipment, on the contrary, is usually gathered just before the true ripening process begins. Some shippers maintain, however, that pineapples one-third ripe may be shipped as satisfactorily as the green fruit.

For the purpose of determining some of the facts regarding the composition of pineapples as influenced by the stage of ripeness at which they are gathered, a number of analyses have been made. The methods employed in this work are essentially those given under the Official Methods for the Analysis of Fruits and Fruit Products.[2] The reducing sugars were determined by the volumetric Fehling solution method; sucrose by double polarization, acidity by direct titration with tenth-normal potassium hydrate with the aid of phenolphthalein. The acid of pineapples is largely citric, but is expressed here as sulphuric. The total hydrolyzable carbohydrates were determined by digesting for two hours 50 grams of the crushed fruit with strong hydrochloric acid (sp. gr. 1.125), cooling, neutralizing with caustic potash, completing to 250 cubic centimeters, and filtering. Reducing sugars in the filtrate were determined by the use of the volumetric Fehling solution method and the results expressed as invert sugar. Nitrogen was determined by the ordinary Kjehdahl method and the solids in the juice were calculated by the use of the tables of H. Ellion from the specific gravity of the juice. Fiber was determined by the usual method for fiber determination in feeds.

The fruits used in this investigation for the most part were gathered from the field by the writer, and the stage of ripeness in every instance was noted, thus largely eliminating uncertainty as to this point. The analytical determinations for the most part were duplicated with concordant results. At this point thanks are extended to the growers in the several districts for their cooperation in this work.

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[1] Florida Sta. Bul. 101.

[2] U. S. Dept. Agr., Bur. Chem. Bul. 107 (rev.), p. 77.

The following table shows the composition of pineapples that ripened normally in the field:

The composition of normally ripened pineapples.

Localities.	Serial No.	Nitrogen.	Acidity as H_2SO_4.	Reducing sugars calculated as invert sugar.	Sucrose.	Total sugars.	Polarization.		
							Direct.	Invert.	Temperature.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	°*V*.	°*V*.	°*C*.
Wahiawa	....	0.06	0.66	3.92	6.78	10.70	5	−3.6	31.7
Do	101	....	.56	3.94	7.97	11.91	6.4	−3.7	32
Do	105	.09	.43	5.10	7.54	12.64	5.8	−3.8	30.5
Do	110	.09	1.03	4.72	9.88	14.60	7.4	−5.1	32.3
Do	111	.07	.86	5.18	10.05	15.23	8	−4.7	32.7
Do	112	.07	.99	4.59	10.12	14.71	8.4	−4.4	32.3
Do	113	....	1.06	3.50	8.47	11.97	6.6	−4.2	30.3
Do	114	.09	.71	4.12	6.93	11.05	4.9	−3.9	31.4
Do	115	.07	.82	3.14	7.15	10.29	5.3	−3.8	31
Do	102	....	.53	3.84	8.36	12.20	6.9	−3.7	31.5
Ahuimanu	106	.08	1.05	3.86	9.45	13.31	7.7	−4.3	31.4
Do	107	.09	1.16	4.18	8.40	12.58	7.1	−3.6	30.8
Do	108	.08	.63	2.78	7.36	10.14	5.4	−4	30
Do	109	.09	.75	3.56	8.12	11.68	6.3	−4	31.7
Haiku	140	....	.45	4.35	6.08	10.43	4.2	−3.5	32
Do	141	....	.68	4	6.97	10.97	4.9	−4	30
Do	142	....	.63	4.87	6.47	11.34	3.9	−4.3	30.2
Do	143	....	.65	4.85	6.85	11.70	4.6	−4.2	28.6
Do	144	....	.61	5.55	6.03	11.58	4	−3.7	30
Average	....	.08	.75	4.22	7.84	12.06	....	....	....

The above data show that Hawaiian pineapples vary considerably in composition. In general the acidity increases with the sugar content, and the average of the total sugars is about equal to that of pineapples from Florida and the West Indies.

In the following table is shown the composition of green pineapples, gathered just before the beginning of the ripening process:

The composition of pineapples just before the beginning of the ripening process.

Localities.	Serial No.	Acidity as H_2SO_4.	Fiber.	Solids in juice.	Hydrolyzable carbohydrates.	Reducing sugars calculated as invert sugar.	Sucrose.	Total sugars.	Polarization.		
									Direct.	Invert.	Temperature.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	° *V*.	° *V*.	° *C*.
Wahiawa	127	0.48	....	7.32	....	3.57	1.96	5.53	1.0	− 1.5	30.5
Do	128	.44	0.19	5.92	5.00	3.17	.78	3.95	.0	− 1.0	30.4
Do	131	.30	.16	....	5.07	3.36	.87	4.23	.4	− 0.7	33.7
Do	132	.33	.17	....	5.10	5.03	1.88	4.91	1.3	− 1.1	30
Experiment station	145	.39	....	7.44	8.02	3.33	3.14	6.47	2 5	− 1.5	31
Average	....	.39	.17	6.89	5.80	3.29	1.72	5.01	....	....	....

The above data are interesting as showing the low sugar content of pineapples at this stage of development. None of the fruit examined showed any yellow color, but in each instance the characteristic pale-green color around the basal eyes, which always makes its appearance just before the development of a yellow color, had developed. The appearance of this pale-green color, together with a flattening of the eyes, is the guide by which the fruit is selected for fresh-fruit shipment. The results show that green pineapples do not contain an excess of acidity or fiber, and from the percentages of hydrolyzable carbohydrates it is apparent that if the fruit is gathered at this stage it can never develop a normal sugar content. Numerous tests at all stages of ripeness have failed to reveal the presence of starch or dextrin in pineapples. It is noteworthy that the ratio of reducing sugars to sucrose at this stage is practically the reverse of that found in the normally ripened fruit.

With the view of determining what changes take place in the fruit in ripening after having been gathered green, a number of pineapples were held at the station until fully ripe. The time required for the completion of this process was usually about three weeks. The following table shows the results of this examination:

The composition of pineapples which ripened after being picked green.

Localities.	Serial No.	Acidity as H_2SO_4.	Fiber.	Solids in juice.	Hydrolyzable carbohydrates.	Reducing sugars calculated as invert sugar.	Sucrose.	Total sugars.	Polarization.		
									Direct.	Invert.	Temperature.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	°*V.*	°*V.*	°*C.*
Wahiawa	133	0.53	0.20	....	5.32	1.48	3.92	5.40	2.4	−2.6	30.7
Do	134	.60	.21	6.78	3.57	1.13	2.26	3.39	1.3	−1.6	28.4
Do	135	.55	.21	6.04	4.75	1.19	3.17	4.36	2.0	−2.0	32.8
Do	136	.63	.25	6.54	3.75	1.06	2.26	3.32	1.1	−1.8	29.1
Experiment station	146	.49	....	5.30	....	1.33	2.06	3.39	1.1	−1.5	32.4
Do	147	.39	....	5.13	....	1.27	2.03	3.30	1.0	−1.6	29.2
Do	148	.39	....	4.99	....	1.37	1.10	2.47	0	−1.4	31.4

The most important changes which took place in the ripening of these pineapples were the conversion of reducing sugars into sucrose, the development of flavor, and a breaking down and liquefaction of the tissues. True fiber and acidity were not materially changed.

The composition of pineapples, one-fourth ripe, is shown in the following table:

The composition of pineapples when about one-fourth ripe.

Localities.	Serial No.	Acidity as H_2SO_4.	Solids in juice.	Reducing sugars calculated as invert sugar.	Sucrose.	Total sugars.	Polarization.		
							Direct.	Invert.	Temperature.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	°*V.*	°*V.*	°C.
Wahiawa	126	0.62	7.34	3.03	3.79	6.82	2.8	−2.0	32
Do	129	.59	7.56	2.53	3.34	5.87	2.2	−2.1	28.4
Do	130	.59	8.36	2.83	3.83	6.76	2.6	−2.3	29.4
Experiment station	149	.72	9.20	2.77	5.89	8.66	4.5	3.0	30.8
Do	150	.75	10.93	2.56	5.25	7.81	4.0	−2.7	30
Average	....	.65	8.68	2.74	4.42	7.16	....	....	....

These data show that sucrose is developed at a considerable rate during the early ripening process, although the fruit at this time had stored up only about one-half of its normal sugar content.

The next table shows the composition of the fruit when it is approximately half ripe.

The composition of pineapples when half ripe.

Localities.	Serial No.	Acidity as H_2SO_4.	Solids in juice.	Reducing sugars calculated as invert sugar.	Sucrose.	Total sugars.	Polarization.		
							Direct.	Invert.	Temperature.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	° *V.*	° *V.*	° *C.*
Wahiawa	116	0.78	11.83	2.74	7.33	10.07	5.7	−3.6	31.8
Do	117	.67	10.36	2.61	6.70	9.31	5.0	−3.5	31.7
Do	124	.63	....	2.38	6.83	9.21	4.9	−3.8	30.5
Do	125	.54	....	4.16	6.09	10.25	5.0	−2.7	32.2
Average	....	.65	....	2.97	6.73	9.70	....	....	....

There is a rapid accumulation of sucrose in the ripening of the pineapple. If the fruit is picked at the half-ripe stage and allowed to ripen thoroughly, it will develop a normal flavor and be a highly desirable product.

From the foregoing data it is shown that green pineapples contain a small percentage of sugars, and if gathered at this stage never develop into desirable fruit. As the ripening process proceeds normally, sugars are stored up at a rapid rate, so that by the time the fruit is half ripe it contains a fairly high percentage of both reducing sugars and sucrose; and if gathered and allowed to ripen will mature into a highly edible fruit. The acidity of green pineapples is practically the same as that of the ripe fruit, whereas the ratio of reducing sugars to sucrose is reversed.

As pointed out above, the changes in pineapples that ripen after having been gathered are those of rearrangement, rather than the production of sugars. The composition of the fruit shows that it contains no substance of any consequence that could be converted into sugars, and therefore the total sugar content of pineapples does not increase after being gathered. It is a recognized fact in plant physiology that sugars may result from two different processes—first, from the direct action of chlorophyll in the chlorophyll-bearing cells, and secondly, from a breaking down of other carbohydrates. In some instances there is an accumulation of starch in plant organs which later is hydrolyzed into sugars. In the pineapple, since starch was never found in the fruit, it is safe to conclude that the sugar stored up in normally ripening pineapples is manufactured in the chlorophyll-bearing cells of the leaves and then transferred to the fruit;

hence when the fruit is severed from the stalk all communication with the source of sugar is broken, and therefore its accumulation is permanently stopped.

The cells of green pineapples, as seen under a high-power microscope, contain a thickened layer on the interior of the cell walls, and it is with difficulty that the juice is expressed from the cells. As the ripening process proceeds this thickened layer is gradually dissolved until at maturity the cell walls are extremely thin and easily ruptured. If pineapples are gathered green and allowed to ripen, it has been found that there is a dissolving of this thickened coat on the cell walls, thus apparently increasing the percentage of juice in the fruit without materially changing the concentration of the juice. Later a microchemical study of these changes will be made.

Thanks are extended to Dr. Wilcox for advice and many suggestions in this work; also to Miss Alice R. Thompson for valuable analytical assistance.

REPORT OF THE AGRONOMIST.

By F. G. Krauss.

Problems affecting the culture of rice and cotton continue to be the main lines of inquiry of this division, as for several years past.

RICE INVESTIGATIONS.

IMPORTS AND EXPORTS.

The increasing importations of rice from Japan, which amounted to 27,886,102 pounds, valued at $717,064 in 1909, as against 9,656,796 pounds, valued at $221,116 in 1905, has resulted in a gradual and finally a marked decrease in the production of this important crop in Hawaii.

The following table gives the United States customs statistics covering the imports and exports of rice to and from Hawaii during the period referred to above:

Imports of rice into Hawaii.

Year.	Japan.		China.		United States.	
	Amount.	Value.	Amount.	Value.	Amount.	Value.
	Pounds.	*Dollars.*	*Pounds.*	*Dollars.*	*Pounds.*	*Dollars.*
1905	9,656,796	221,116	11,964	245	9,983,491	303,029
1906	12,496,396	283,653	22,600	529	4,129,643	164,683
1907	21,012,842	539,021	13,906	351	755,050	34,144
1908	26,695,642	740,975	6,485	155	95,524	4,821
1909	27,866,102	717,064	13,966	314	109,300	4,358

The exports to the United States from Hawaii during the same period were:

Exports of rice to the United States from Hawaii.

Year.	Amount.	Value.
	Pounds.	*Dollars.*
1905	2,771,083	84,414
1906	5,739,500	223,012
1907	3,324,107	147,439
1908	3,038,624	140,768
1909	5,823,585	255,210

These inroads upon one of Hawaii's staple products are not based upon a competition in prices, but upon quality. The imported product sells at from 25 cents to $1 more per 100 pounds than does the locally grown rice. The Japanese, who are the principal consumers of rice in Hawaii and the sole importers of the Japan products, demand a distinct type of rice whose characteristic culinary qualities are inherent in certain varieties, and also in large part due to the conditions of growth.

RICE IN JAPAN.

With a view of determining, if possible, the varieties and cultural conditions under which the preferred Japan rices are grown, the writer was authorized by the United States Department of Agriculture to undertake such investigations. Accordingly, the fall months of 1909 were devoted to a critical study of the industry in Japan. Valuable data were obtained at several experiment stations, of which the Central Experiment Station at Nishigahara (near Tokyo), the Kinai Branch Station at Kashiwara (near Osaka), and the Kiushiu Branch Station at Kumamoto (in the famous rice region of Kyushu) are worthy of special mention. The last two stations are devoted almost wholly to rice investigations.

At the Kinai Station a fine opportunity was offered to study varieties. Here have been brought all the types of rice grown in the Empire. After six years' study and comparison these have been grouped under 600 more or less constant varieties or strains sufficiently distinct for classification. A hundred of the most distinct types were obtained for experimental purposes, and are now under comparative tests with the best Hawaiian varieties. After inquiry among rice specialists and personal study, the four following standard varieties were determined upon as most promising for Hawaiian conditions, from both culinary and cultural standpoints. The varieties Omachi and Shinriki are the two types now almost exclusively exported to Hawaii, as they find special favor among the large Japanese population, and bring the highest market prices. The varieties Benkei and Miyako are considered of the highest quality in Japan, and are in great demand by those who can afford to buy them. A hundred pounds of choice seed of each of the four varieties were obtained for distribution among Hawaiian growers. Eight prominent growers availed themselves of seed for this spring's planting, and reports of the results of their experiments are now looked for.

The following descriptions of the above varieties are based on a study of pure strains made in the field at the Yamaguchi Demonstration Station, which is situated in the center of the region from which nearly all the Japan rice entering Hawaii is imported, and where these particular varieties are said to attain their highest perfection. A comparison of the behavior of these varieties grown at the station rice trial grounds during the past spring, from the identical stocks described above, should be of value as determining their adaptability to Hawaiian conditions, from the cultural side, at least. Their culinary qualities are, of course, as yet to be determined, and upon this will depend their acceptability to the consumer.

DESCRIPTION OF FOUR NEWLY INTRODUCED JAPAN RICES (PLATE III).

1. Miyako. Average height of plants, 48 inches; inclined to lodge; average number of fruiting culms per clump, 16; panicles large and compact; kernels medium size, awnless; a fair yielder, medium early. Considered the very best variety grown in Japan.

2. Benkei. Average height of plants, 40 inches; stands up well; average number of fruiting culms per clump, 18; panicles compact and heavy; kernels large, awnless; good yielder, early maturing. Considered a promising new variety in Japan, of fine culinary qualities.

3. Omachi. Average height of plants, 48 inches; slightly inclined to lodge; average number of fruiting culms per clump, 15; panicles large but rather loose; kernels medium size, awned; yields well; a type not likely to be appreciated by the Hawaiian grower because of its awned glumes; but strongly recommended by the Japan experiment stations for trial. It is a standard variety of Japan; extensively exported to Hawaii.

4. Shinriki. A standard variety in Japan; largely exported to Hawaii. Of more recent development than Omachi and by some considered an improvement. Average height of plant, 42 inches; stands up well; a heavy tillering sort, averaging 20 to 30 fruiting culms per clump; panicles small to medium; kernels small, awnless; good yielder; classed as a late variety in Japan, but the writer found it maturing at about the same time as the other varieties described above. Considered by the writer a promising variety for Hawaii.

The table below gives the results of the first season's cultural trial of the above varieties in comparison with the old type of Japan rice heretofore grown to a limited extent in Hawaii. The seed was sown February 4, the seedlings transplanted March 15, and the crop harvested June 3, 1910, the growing period being 119 days for all varieties.

Comparative tests of new and old types of Japan rice (spring crop, 1910) grown without fertilization.

Name of variety.	Average height of plants.	Average number of fruiting culms.	Yield of paddy from 100 clumps.	Yield of straw from 100 clumps.	Character of glumes.
New types:	*Inches.*		*Pounds.*	*Pounds.*	
Benkei	28	16.2	4.0	3.28	Awnless.
Miyako	33	16.7	3.75	3.53	Do.
Omachi	31	17.8	4.87	3.61	Awned.
Shinriki	26	23.1	4.23	3.06	Awnless.
Old type:					
Japan rice No. 153	29	19.8	4.15	4.62	Do.

In comparison with the old type Japan rice, No. 153, both Omachi and Shinriki, the two standard sorts in Japan, which are the only varieties imported into Hawaii, outyielded the former. This is in itself a distinct gain should the quality be maintained in future culture. The variety Benkei, which especially appealed to the writer from a cultural standpoint as he saw it growing in Japan, did not quite equal the yield of the old type, but seems promising. Miyako, considered the best type of rice grown in Japan, gave the smallest yield. It is also considered a rather light yielder in Japan, but its superior quality and consequent high price makes it a leading sort in favored localities. The heavy tillering qualities of Shinriki appear to have been maintained in this trial. From the standpoint of yield, it would appear that Omachi and Shinriki are the most promising sorts. The main objection of the Hawaiian grower to the former variety is its bearded glumes. The Japanese have effected a cross between these two varieties with a view to inducing heavier tillering, beardlessness, and the superior flavor of Omachi in the hybrid. The two former qualities have been effected to a marked degree. Sufficient stock of the hybrid has not yet been grown to make a culinary test. The station was fortunate in securing a small quantity of this hybrid seed for trial.

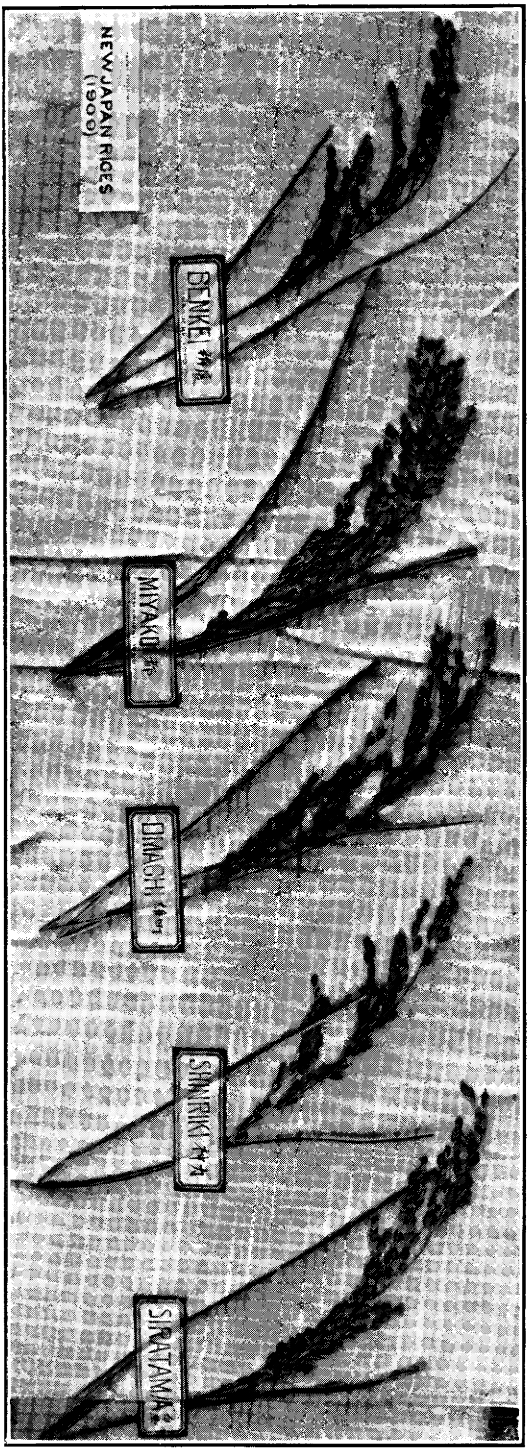
The figures in Plate III show typical panicles of the several rices just described, and in addition, the variety Saratama, a promising variety, which, owing to its late maturity, can not be described in this report. Panicles of less acceptable types of Japanese rices are shown in Plate IV.

SELECTION AND BREEDING.

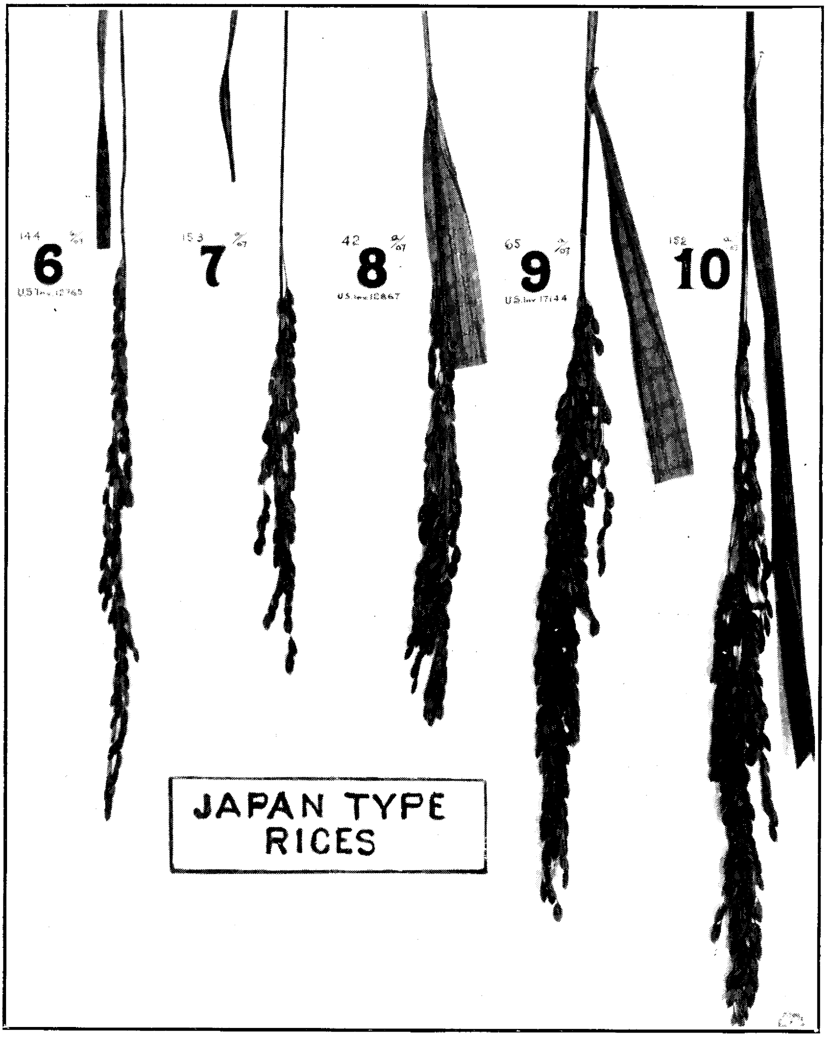
In addition to the variety tests of new Japanese and Chinese rices, noted above, the development of pure strains of the best old type is being continued. Some of these strains are now in the seventh generation of selection. A number of these show a marked improvement over the original type, as shown in comparative cultural tests. Increase in yield has been less noticeable than greater purity and uniformity.

Unfortunately, much difficulty has been experienced in inducing growers to perpetuate improved station strains in a pure state. Only limited quantities of station seed are available for distribution, so that growers are dependent upon themselves to produce such seed as they may need for general plantings. However, a season or two of commercial culture almost invariably results in a mixture of varieties. Aside from immediate local benefits, the importance of maintaining pure strains of high-bred rices is well illustrated by a request which came from a rice broker in New Orleans. The station was applied to for samples of choice seed in the hope that a select Hawaiian stock could be obtained to replace the large importations of South American seed used for planting. This is owing to the prevalence of red rice in American seed. A number of local growers submitted samples, but the only stock acceptable was a station strain, for which a substantial advance over current local prices was offered, if obtainable in carload lots. However, too limited an amount was available to make it an object to the purchaser. This experience appears to have renewed the interest in the possibility of growing rice for seed purposes, which has been urged persistently by the

PLATE III.



TYPES OF RICE CONSIDERED OF HIGHEST CULINARY QUALITY IN JAPAN.



JAPANESE RICES NOT ACCEPTABLE TO JAPANESE CONSUMER.

station. One grower has asked the station's cooperation in developing this phase of the industry.

Of the several new varieties of rice introduced by the station in past years, variety No. 19 (S. P. I. No. 12508), introduced in 1907, appears to have at last found favor among the more intelligent growers. The Oahu rice mill of Honolulu reports having milled 480 bags, equivalent to 24 tons, during the past season. Other growers and millers are yet to be heard from. Mr. A. Hanneberg, of the Kaneohe Rice Mill Co., who produced several hundred bags of the above lot, speaks enthusiastically concerning this variety and states that it is well suited to the salt-marsh lands, which heretofore were devoted only to inferior rice. Should its adaptability to salt lands and a maintenance of high quality hold true in subsequent practice, a valuable acquisition will have been added to the resources of Hawaii.

Because of the exceptionally heavy tillering, together with the desirable hard, translucent grain of rice No. 19, efforts have for several years past been made to effect a cross between it and the best type of Hawaiian Gold Seed. The latter variety still remains the standard sort with the white and Chinese population, in addition to being one of the leading varieties of export. Could heavier yields and a clearer grain be obtained in Gold Seed, on the one hand, and the fixed property of fall maturity of rice No. 19 be changed to the "all season" cropping habit, which characterizes the Gold Seed, valuable combinations would be effected.

The difficulty thus far has been to get the two varieties to flower at the same time to permit of cross pollination. As the habits are now so well known, it is believed that the extensive plantings planned for this fall will provide the necessary conditions for hybridization.

A careful study was made of the methods practiced by the Japanese in their rice breeding, which has proved very successful during recent years. It is believed that valuable data were obtained as an aid to the contemplated work at this station.

In the study of tens of thousands of individual plants annually by Japanese investigators a natural hybrid among rice was found to be of rare occurrence, notwithstanding the fact that more than 600 varieties have been grown in close proximity for several years past. These results are in agreement with the writer's findings, but contrary to the generally accepted theory.

ROTATION.

The fertilizer investigations with rice having been assigned to the chemical division, this division has had to do with cultural work only. This has included, during the past spring experiments in crop rotation and green manuring, the latter in cooperation with the chemical division. Barley, one of the cereals extensively used in rotation with rice in Japan, and the established Hawaiian legumes, cowpeas, soy beans, velvet beans, and jack beans (*Canavalia ensiformis*), were planted as rotation crops during the spring, together with the Japanese and Chinese matting plants (*Juncus effusus* and *Cyperus tegetiformis*), which the station has been growing for several years. In addition to the above legumes used as rotation crops, there were planted as green manuring crops *Astragalus sinicus* (the "Genge" or "Renge" of Japan) and *Vicia faba*, the two green-manuring plants most extensively used for rice in Japan. The barleys, of which 50 of the best hulled and naked Japan paddy field varieties were sown, did poorly as a whole, a large percentage failing to head. Some 20 varieties set seed and appear to be fair yielders of grain. All are of very dwarf type, averaging less than 24 inches to tip of spike. Being planted in March, the lateness of season may have had considerable to do with this first poor showing.

Large quantities of barley are imported into Hawaii and its profitable culture in the islands would add materially to their resources. Furthermore, a rotation of a dry-land crop with the submerged culture of rice could not but prove beneficial to the paddy soils, as has been found to be the case in other countries.

The Astragalus used for green manuring proved an entire failure. Planted in March, the seed germinated well, but failed to make more than the feeblest growth. This persisted till the flowering stage and then wasted away, notwithstanding an ample supply of moisture.

The Windsor beans made quite a vigorous growth, but, as in former experimental plantings, failed almost wholly to set seed. It is already quite evident that these two types of green-manuring plants should be planted late in the fall during the coolest season of the year and under moist conditions, such as prevail in paddy fields.

The older-introduced legumes all did well and yielded a large amount of organic matter. Planted in March, the following results were obtained, calculated to acre yields.

Plat III: Soy beans. Variety, Mammoth Yellow; days to turning-under stage, 63; height, 24 inches; yield of green vegetable matter (including main roots), 10,125 pounds; yield as cured fodder (including seeds), 2,500 pounds; yield of seed, 675 pounds; distance of rows, 24 inches.

Plat IV: Velvet beans (*Mucuna utilis*); days to turning-under stage, 75; height of main growth, 28 inches; yield of green vegetable matter (including main roots), 15,300 pounds; yield as cured fodder, 3,420 pounds; yield of seed, 145 pounds; distance of rows, 4 feet.

Plat VII: Cowpeas. Clay type; days to turning-under stage, 75; height of main growth, 36 inches; weight of green vegetable matter (including main roots), 32,400 pounds; yield as cured fodder, 7,200 pounds; yield of seed, 1,417 pounds; distance of rows 4 feet.

Plat VIII: Jack beans (*Canavalia ensiformis*); days to turning-under stage, 75; height of plants, 40 inches; yield of green vegetable matter (including roots), 17,000 pounds; yield as cured fodder, 4,060 pounds; seed not mature at this writing; distance of rows, 4 feet.

Planted March 1, a part of each of the different varieties was turned under about the middle of May, excepting the soy beans, which were turned under 10 days earlier. The jack beans were much the latest to mature, but were turned under with the others to permit of uniform decay before planting the succeeding rice crop.

As will be noted from the above, the cowpeas considerably outyielded all the other legumes, both in green matter and seed. This is in concordance with a number of previous tests in which many different kinds of legumes were under trial. However, both the velvet bean and jack bean are much surer croppers, being practically immune from the attacks of aphis to which the cowpea is especially subject. The main objections to jack beans and velvet beans are their slow maturity and less palatability. The soy bean, because of its early maturity, lends itself well to short seasons and will often fit in where legumes of larger yield but slower maturity would be out of the question.

The matting plants have not yet been harvested, but their growth compares favorably with that previously reported.

COTTON EXPERIMENTS.

Although still in the experimental stage, the cotton industry in Hawaii has made substantial progress during the past year. Many inquiries have come to the station concerning varieties and methods of culture. Station seed has been widely distributed for experimental purposes, enough being sent out to plant several hundred acres. It is estimated that fully 500 acres are now planted in the Territory. The largest planting comprises about 80 acres. The first commercial crop has been harvested, and is now in bale awaiting shipment. Samples submitted to experts have been pronounced first class; the highest market prices have been quoted.

As announced in the Annual Report for 1909, two extensive cooperative experiments on a field scale were begun in the early part of 1909. The first harvest of these has been completed, and the results, although far from satisfactory from the commercial side, are nevertheless of great value from an experimental point of view.

KUNIA COOPERATIVE COTTON EXPERIMENT.

Kunia lies on the east approach to the Waianae Range, at an elevation of about 600 feet. The soil is a deep, light, silty loam. The region would be classed as semiarid, the rainfall averaging less than 20 inches. The natural growth is guava, lantana, klu, and an occasional large kukui tree, Opuntia and algaroba. The grasses are rather sparse, but manienie, piipii, and other native grasses are met with. The whole growth is characteristic of dry regions. No previous crop had been grown on the lands under experiment.

Preliminary to the experiment the land was plowed in October of the previous year to a depth of at least 24 inches, several times harrowed, and finally plank-dragged, which left the soil in fair condition for planting.

On February 16–19 one-fourth acre was sown to each of the following varieties, Caravonica "wool" (Plate V), Egyptian (Mit Afifi), Sea Island (Georgia and Florida strain), Sea Island ("Seabrook"), and upland "Chinese," as an early planting; and a month later another one-fourth acre was sown as a late planting. All varieties were planted 2½ by 5 feet apart, giving 3,480 plants per acre, except Caravonica, which was planted 5 by 10 feet apart, or at the rate of 870 plants per acre. Each plat consisted of an additional half acre, a third of which was left fallow, a third planted to jack beans as a green manuring or rotation crop, and the remaining third was planted to soy beans and cowpeas. This half of each acre plat was then to be followed with cotton in the succeeding year; thus, in the second year (1910), a comparison between 1 and 2 year old cultures was obtained.

The results of the first year's harvests are given in the following table:

Yields of cotton from first year's harvest, Kunia cooperative experiment.

Plat No.	Variety.	Yield of seed cotton.		Yield of lint.	Yield of seed.	Percentage of lint to seed.	Quoted market value of lint.
		Weight at picking (¼ acre).	Weight after 6 months (½ acre).[1]				
I.	Caravonica "wool":	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Cts. per lb.*
	Early planting	32½	54	24	30	44.4	0.29
	Late planting	22					
II.	Egyptian, Mit Afifi:						
	Early planting	95	131	44½	87	33.3	.29
	Late planting	37½					
III.	Sea Island, Georgia-Florida strain:						
	Early planting	107	169	50½	170	29.4	.31
	Late planting	64¼					
[2]IV.	Sea Island, "Seabrook":						
	Early planting	397¾	392	106	236½	30.8	.31
V.	Upland, "Chinese":						
	Early planting	115¾	211	71	140	33.6	.15
	Late planting	119¾					

[1] After the first weights were taken the cotton harvested from the early and late planting of each variety was unintentionally bulked together; hence, the cured weights represent the yield of the two plantings—the product of a half acre. To calculate to acre yields, multiply separate plantings by 4, and the totals of the 2 plantings by 2.

[2] Plat IV, consisting of 1 full acre of early planting, was divided into 13 sections for a fertilizer experiment, the detailed results of which will be reported by the chemist in a later bulletin.

The low yields from this experiment may be attributed to several causes. The rainfall, amounting to about 22 inches for the year, was doubtless inadequate for optimum growth on rough and newly

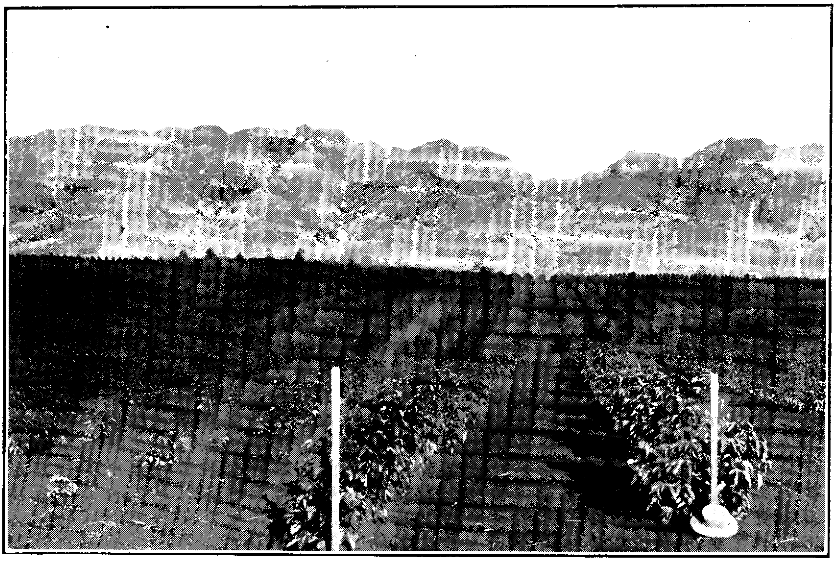


FIG. 1.—CARAVONICA "WOOL" COTTON 6 MONTHS FROM SEEDING.

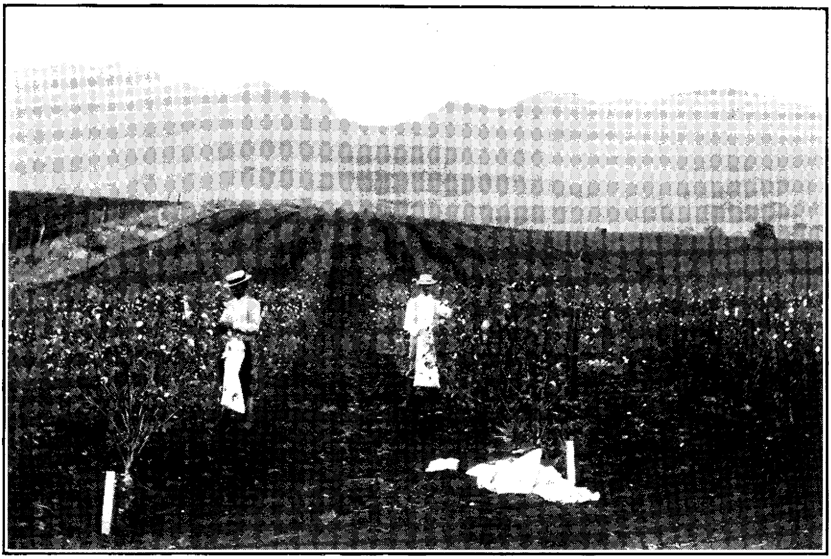


FIG. 2.—CARAVONICA "WOOL" COTTON 9 MONTHS FROM SEEDING.

COOPERATIVE COTTON EXPERIMENTS.

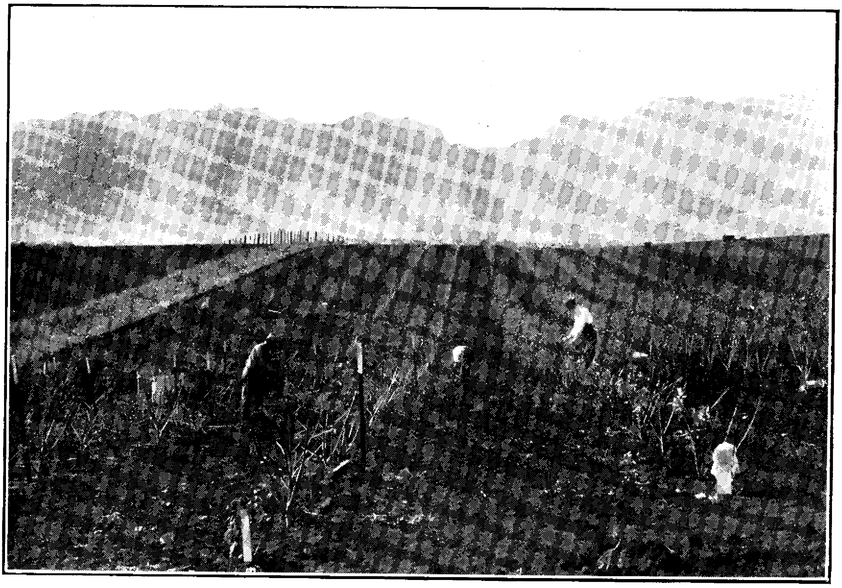


FIG. 1.—PRUNING 1-YEAR-OLD CARAVONICA "WOOL" COTTON.

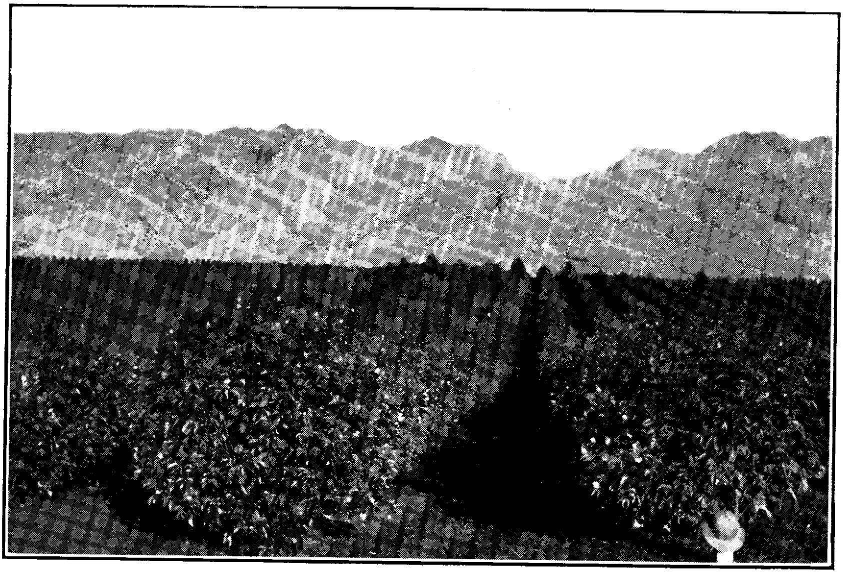


FIG. 2.—SECOND SEASON'S GROWTH OF CARAVONICA "WOOL" COTTON.

COOPERATIVE COTTON EXPERIMENTS.

broken ground. Although the germination was excellent, cutworms attacked the young seedlings from their very appearance above ground, destroying as high as 80 per cent of the stand in some cases. This necessitated repeated partial reseeding. In the case of the early plantings, four reseedings were made, and in the late plantings, two reseedings. These reseedings ranged from 20 per cent upward. It will be noted that the late plantings gave much lower yields than the early plantings, and this gives further proof that the great decrease in yield is due to irregularity of stand. It is safe to say that the original early planting outyielded any subsequent plantings twofold, so that a full stand of the first seeding would unquestionably have given fair yields as judged by mainland standards.

Comparatively little damage was traceable to the bollworm. But during the latter part of the season this pest was much in evidence among the general plantings of the development company, whose cotton fields surrounded the experimental plats. The fertilizer experiments gave good evidence of the value of proper fertilization, as has already been pointed out by the chemist in his report.

The importance of selecting suitable varieties is not fully brought out by the table of yields, but a study of the plants in the field indicates that the Upland type, while slightly outyielding the next best in point of yield, gave insufficient increase to make up for the difference in price.

The Egyptian cotton showed fine individual plants, but the poor stand reduced the acre average below all other varieties, except the Caravonica. This latter variety, as is well known, yields poorly the first year, even under favorable conditions.

The best sections in the fertilized Sea Island plat, as well as the best plants in Plat III, containing another strain of Sea Island, give promise for this variety in seasons of average rainfall. This variety should receive further consideration, because of the high quality maintained by the fiber under adverse conditions of growth.

Judged from the standpoint of general growth, and the subsequent heavy squaring of the Caravonica cotton, this variety unquestionably gives the greatest promise as a drought resister, and would seem the variety especially adapted to this locality. Plates V and VI give a series of views of the Caravonica plat. Figure 1, Plate V, illustrates the growth attained at six months from seed. Figure 2 shows the beginning of the harvest, nine months after planting. While the plants as a whole yielded an average of less than 3 ounces per plant, owing to poor stand and irregularity of the remaining plants, a number of selected specimens yielded over 1 pound per plant. Figure 1, Plate VI, shows the partially dormant plants twelve months after planting, as they were being pruned. Figure 2 of the same plate shows the same plants at the present writing, about eighteen months from time of planting. The plants are heavily loaded with squares, blossoms, and young bolls, from 100 to 500 fruits in the different stages having been counted per plant. Although less than 6 inches of rain has fallen in the past half year, the plants are growing vigorously, and with every prospect of giving a good yield. It is interesting to note that the irregularity in the size of the plants, presented in the first year, has largely been overcome during the fore part of the second season. All vacant places have been filled in by transplanting one-year old stocks which, with few exceptions, are growing well.

On the basis of the results of the past season the company controlling these lands have added 50 acres of Caravonica to the previous plantings, making a total of about 75 acres.

WAIPAHU COOPERATIVE COTTON EXPERIMENTS.

The Waipahu cooperative cotton experiment is located on the uplands bordering the edge of the upper irrigated cane lands of the Oahu sugar plantation, which faces the Koolau Range. This experiment is a duplication of the Kunia experiment, excepting that the entire acre of each experimental plat was sown in two plantings, instead of half that amount, as at Kunia. The elevation is approximately the same, but the rainfall is somewhat greater, estimated to be about 35 inches per annum. However, the land is more exposed to strong cold winds. A tract of virgin grass land, typical of the region, was selected for the experiment. This was plowed to a depth of about 16 inches in October. The old grass stools littered the field badly and it required considerable tillage to get the field in planting condition. All plantings were completed within a week after those at Kunia.

The results of the first year's harvest are given in the following table:

Yields of cotton from first year's harvest, Waipahu cooperative experiment.

Plat No.	Variety.	Yield of seed cotton (½ acre).	Yield of lint.	Yield of seed.	Percentage of lint to seed.	Lint calculated to acre yields.
I.	Sea Island, Georgia-Florida strain:	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*
	Early planting	62½	19½	43¼	31.2	39
	Late planting	42¾	13¼	29½	30.9	26½
II.	Sea Island, "Seabrook":					
	Early planting	277¾	87½	190¼	31	87½
III.	Caravonica "Wool":					
	Early planting	5¼	2.07	3.18	39.4	4.14
	Late planting	[1] 170	[1] 68	[1] 102	40	[1] 136
IV.	Egyptian, Mit Afifi:					
	Early planting	146¼	50¾	95½	34.7	101½
	Late planting	23½	8	15½	34.2	16
V.	Upland, "Chinese":					
	Early planting	113	39¼	73¾	34.7	78½
	Late planting	35¼	12¾	22½	36.4	25½

[1] Weight in grams.

A comparison of the Kunia yields with those obtained at Waipahu shows a considerably lower yield for the latter. This can, to only a small degree, be attributed to lack of moisture, because although the soil became quite dry as the season advanced, certain sections in the fertilizer plat gave yields five times as great as the untreated sections under the same condition of moisture. From this it would appear that in these newly opened lands there exists a decided lack of available plant food. The striking differences between the early and late plantings, which were even greater at Waipahu than at Kunia, are largely to be ascribed to a lack of moisture, since at this season no rains occur. From these experiments and the results obtained during the present season, it would seem that early planting is essential on lands in these localities.

The same drawbacks from cutworms experienced at Kunia were repeated here and necessitated the same number of reseedings. It will thus be seen that this pest in itself is an important problem with the cotton grower. The low yields are, of course, in large part to be ascribed to the poor stands and irregular ages of the plants. This is well illustrated by the fact that the yield of 101½ pounds of lint per acre in the case of the early planted Egyptian cotton, represented about 77 per cent of a full stand, without considering the fact that about 60 per cent of the plants represented a second, third, and fourth replanting. It may be further noted that a large number of individual plants from the first sowing averaged 250 bolls per plant, equivalent to at least 2 pounds seed cotton, which would yield approximately 11 ounces of lint. From the above, and from results obtained at the station trial grounds, it would appear that the Egyption cottons have many qualities to recommend them for trial under Hawaiian conditions.

The Caravonica cotton made a much less satisfactory growth at Waipahu than at Kunia, and the yield was nil for all practical purposes. They again started off slowly during the present spring, but as the warm weather came on, appeared to respond quite markedly. However but few bolls have set, and a number of these are falling prematurely, as is also the case on the acre planting made on a neighboring plantation. The cause for this phenomenon has not as yet been determined.

YIELDS.

No data are at hand to show the exact yields obtained from commercial plantings. Reports of yields up to 1,800 pounds of seed cotton per acre for Sea Island and Egyptian cottons have been received from reliable sources, but the areas under consideration have usually been less than an acre. No official report has as yet been made covering the yields of Caravonica cotton from the 25-acre planting at Makaweli, Kauai, but it is understood to have been satisfactory for a first season's crop. The cotton from the private planting of 20 acres at Kunia has not been weighed at this writing, but will probably yield at a somewhat lower rate than on the experimental plat.

Mr. E. C. Smith reports that his 40 plants of Caravonica cotton at the Peninsula, planted in January, 1908, have yielded during the 12 months preceding December 31, 1909, 280 pounds of seed cotton. This would be equivalent to a yield of 4,760 pounds per acre.

Owing to the serious infestation with the bollworm of the cottons grown experimentally at the station grounds, the cultural data of which formed the basis of Press Bulletin No. 24, the second year's yield of merchantable lint was very low.

The yields of all the varieties entering the second year promised an advance over the first year. The Florida and Georgia strains of Sea Island matured their first bolls May 10–25, as against August 8 of the previous year; but the bolls, while of good size and yielding an excellent quality of lint, proved to be infested with the bollworm in very large proportions. This increased as the season advanced and prevented the completion of records of yield for comparison with the first year's crops.

The Caravonica cottons, with the exception of test No. 104, fared similarly. Test No. 104, however, which was located in another field, gave good results both in yield and freedom from pests. The 26 plants in this test were planted in July, 1907. The average yield per plant was 15.2 ounces of seed cotton, as against 6.3 ounces the year previous. The three best selections gave the following yields: Selection 5, 2.43 pounds seed cotton; selection 6, 2.5 pounds seed cotton; selection 9, 3.43 pounds seed cotton.

The main lesson to be learned from this experiment is the seriousness of the pest factor, as has already been pointed out by the station entomologist.

COTTON BREEDING.

During the past year a good foundation has been laid for the cotton breeding work planned a year ago, as announced in Press Bulletin No. 24. During the year an acre planting of the most carefully selected Caravonica seed obtainable and a smaller patch of equally good Sea Island were planted for seed production.

Some 30 standard varieties, represented by the American Upland, Sea Island, Egyptian, and Caravonica types, together with the two wild native cottons, and a Cuban red and a Peruvian tree cotton, were planted in a comparative test. All have done well, and all excepting the last four have completed their first crop. Careful study and copious notes have been made of each variety, and a large num-

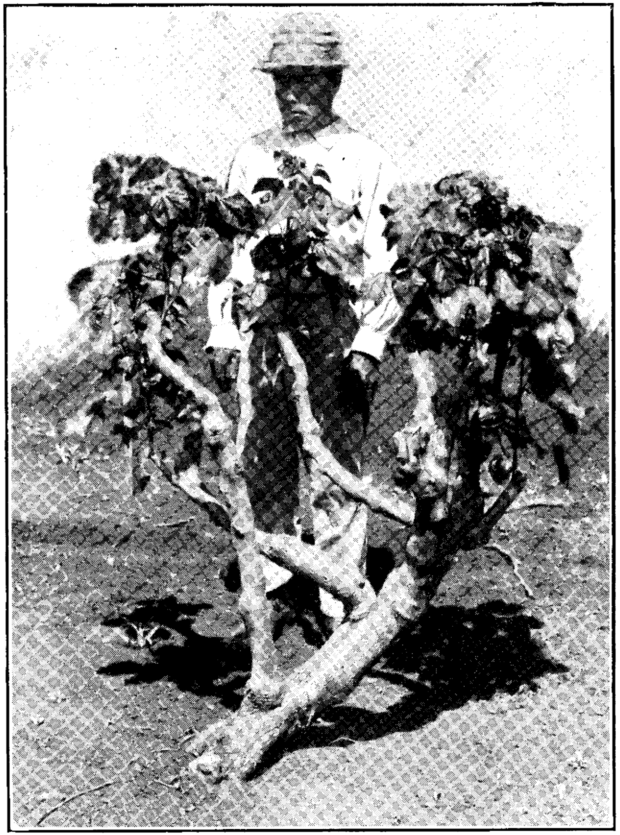


FIG. 1.—THREE-YEAR-OLD CARAVONICA COTTON TREE BUDDED TO SUPERIOR STRAIN, 3 MONTHS' GROWTH AFTER BUDDING.

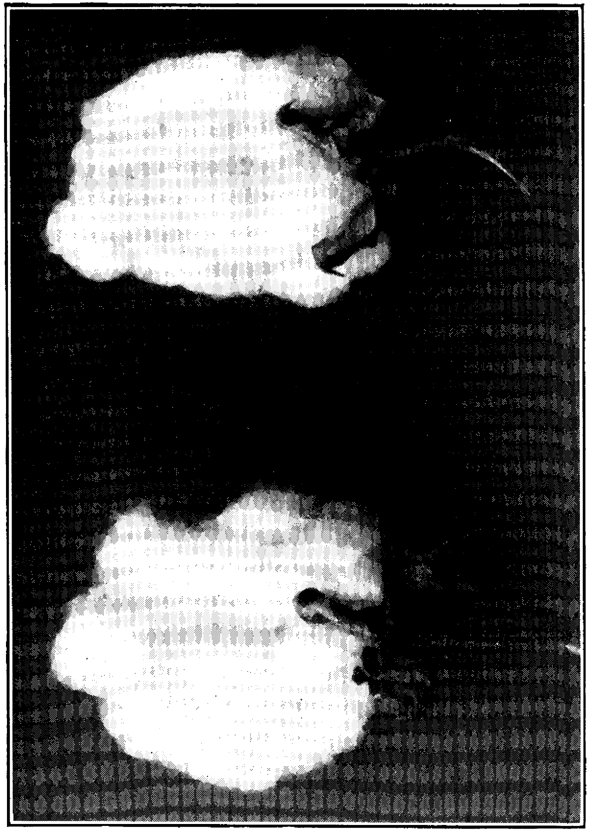


FIG. 2.—IDEAL TYPES OF CARAVONICA "WOOL" COTTON BOLLS.

(Two-thirds natural size.)

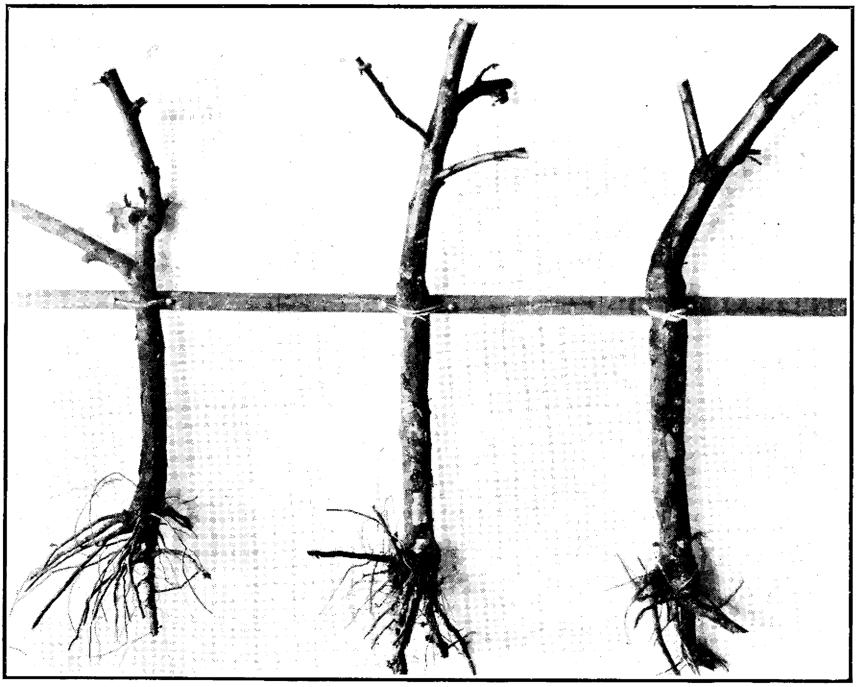


FIG. 1.—ONE-YEAR-OLD CUTTINGS OF CARAVONICA COTTON.

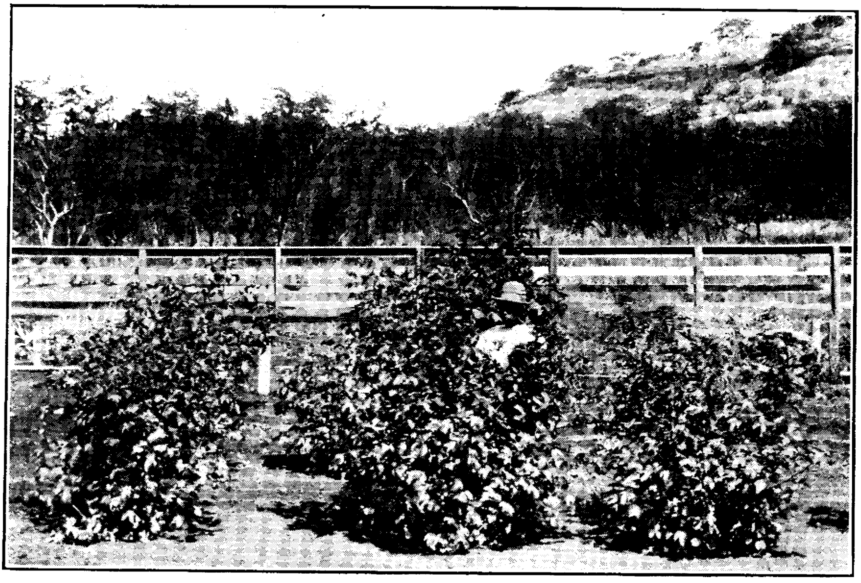


FIG. 2.—PLANTS GROWN FROM ABOVE CUTTINGS, 6 MONTHS AFTER TRANSPLANTING.

ber of superior individuals selected as breeding plants. All the inferior plants not destroyed outright have been budded over to the selections. Twelve hundred buds were inserted. Of these, 380, representing 31 per cent, have made satisfactory growth. A large number of cuttings were also made. Of these from 10 to 60 per cent took root. While these percentages are low, the material available was not always good. A number of minor trials under more favorable conditions were very successful, exceeding 80 per cent.

Plate VII, figure 1, shows a 3-year-old Caravonica tree budded over to one of the superior selections shown in figure 2 of the same plate. Eight of the ten buds inserted are making a vigorous growth. Plate VIII, figure 1, illustrates average specimens of the 1-year-old Caravonica cotton cuttings, described in the Annual Report for 1909. In this original experiment, 90 per cent of the Caravonica cuttings rooted. Figure 2 shows the same cuttings six months after transplanting to permanent location. They are making a very vigorous growth and are blooming profusely, a number of the plants averaging a hundred young bolls at this writing.

For the propagation of selections by budding it is now planned to grow seedlings of a vigorous sort in the nursery, as with the common fruits, and when these are from two to three months old to bud low to a single stem. This has already been demonstrated as feasible by Mr. E. C. Smith, a pioneer worker with this method. In Mr. Smith's experiments practically every bud inserted has grown. The day seems near at hand when one may purchase budded seedlings of a pure strain of superior Caravonica cotton by the hundred or thousand. These would be planted out in orchard rows like so many fruit trees, and a full year of cultivation saved, with a possible saving in cost.

MISCELLANEOUS CROPS.

In addition to the comparative tests of rices and cottons, the usual plantings of new crops, to test their adaptability to Hawaiian needs and conditions, have been under trial during the past year. The number of varieties under test during the past spring has exceeded 200. A large proportion of these was personally selected in China and Japan. Among the above a number of sorghums from Africa, and legumes from Japan, give special promise. These will be reported upon in a forthcoming bulletin.

During the year numerous calls were made upon this division for advice pertaining to problems affecting field crops other than rice and cotton. Among these may be mentioned an extensive cropping system involving a 50-acre cooperative experiment, which was planned for the Molokai Ranch Co. This experiment is now well under way, and is showing substantial results.

TARO.

The gradual decline of the taro crop on a 9-acre plantation near Honolulu has been given some attention during the year. An investigation of the fields during the height of the harvest season a year ago showed a deplorable state of affairs. Different patches showed from 20 to 60 per cent of the corms, the edible underground portion of the plant, to be decayed. The decayed portions were returned to the patches "as fertilizer," and in replanting the "hules" from diseased plants were freely used. No fallowing or rotation had been practiced for 20 years. Such a practice could not be expected to bring about other results. The general treatment outlined in Bulletin No. 2 of the station, entitled The Root Rot of Taro, by the former agriculturist, was recommended. The results thus far are very encouraging. Not more than 5 per cent of diseased plants are apparent at this time, a year after the treatment began.

The agronomist wishes to make acknowledgment of the financial aid and encouragement rendered by a number of the prominent rice growers of the Territory in furthering the rice investigations in China and Japan. Likewise thanks are due to the Japanese and Chinese officials who freely gave information and seeds during the oriental trip. To the members of the station staff who have made valuable suggestions and rendered material aid in various phases of the work in hand, and especially to my former associates, Messrs. Q. Q. Bradford and V. S. Holt, I wish to express my appreciation for their work on cotton. The former did practically all the budding.

A full report of the writer's observations on rice and cotton investigations in China and Japan appeared in The Hawaiian Forester and Agriculturist, beginning with the May, 1910, issue.

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1421 Issued April 9, 1912.

HAWAII AGRICULTURAL EXPERIMENT STATION,

E. V. WILCOX, Special Agent in Charge.

ANNUAL REPORT

OF THE

HAWAII AGRICULTURAL EXPERIMENT STATION

FOR

1911.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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C. K. MCCLELLAND, *Agronomist.*
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F. A. CLOWES, *Superintendent of Hawaii Substations.*
J. DE C. JERVES, *Superintendent of Homestead Substation.*

LETTER OF TRANSMITTAL.

Hawaii Agricultural Experiment Station,
Honolulu, Hawaii, October 2, 1911.

Sir: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year ended June 30, 1911.

Respectfully,

E. V. Wilcox,
Special Agent in Charge.

Dr. A. C. True,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. True, *Director.*

Publication authorized.
James Wilson,
Secretary of Agriculture.

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ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1911

SUMMARY OF INVESTIGATIONS.

By E. V. Wilcox, *Special Agent in Charge.*

BUILDINGS AND GROUNDS.

The new office building erected the previous fiscal year has served well the purpose for which it was erected, and is now used exclusively for the library, general office, and office of the entomologist. The quarters of the agronomist are in one portion of the old office building, which has been completely remodeled to accommodate the work of the departments of chemistry and agronomy. During the fiscal year ended June 30, 1911, a ginhouse was built for the better handling of the experimental cotton crops. In the center of the building the roller gin and gasoline engine are placed on cement bases, while around the sides of the building are arranged bins for holding seed and lint and for curing the seed cotton before ginning. Among the needs of the station for new buildings there is none greater than that of a glass propagating house in which the various seedlings can be properly protected from rain, wind, insects, and birds, and in which temperature conditions can be controlled, particularly to furnish bottom heat for certain seeds which require such heat in order to germinate properly. It is hoped that sufficient money may be obtained from Territorial funds during the next fiscal year to construct such a propagation house.

When the ground upon which most of the buildings of this station stand was formally turned over to the Department of Agriculture by the Navy Department a 2-acre plat located on Magazine Hill, near the front wall of Punchbowl, was also included. This ground has been cleared and planted to corn, cotton, and broom corn. The plat is in a very dry locality, most of the trade wind rains failing to reach it. Moreover, the soil is rather sandy and porous. An experiment has been carried on this year to determine how successfully corn, broom corn, and cotton will grow under such dry conditions. The best success was obtained with corn, particularly with the Yellow Creole variety.

On the slopes of Tantalus, at an elevation of about 750 feet, another small area which has previously not been cultivated was cleared and planted in Caravonica cotton, in order to compare the growth of this variety at the higher and the lower altitudes.

CHANGES IN STATION STAFF.

During the year a few changes occurred in the staff of the station. Mr. F. G. Krauss resigned and his place was filled by the appointment of Mr. C. K. McClelland. Miss Alice R. Thompson being on a furlough for a year, it became necessary to appoint another assistant chemist. This position has been filled by the appointment of Mr. W. T. McGeorge. Mr. W. P. Kelley, the chemist, has planned for a furlough during the coming fiscal year, and therefore the chemical department will have but two members of the force during the year.

DEMONSTRATION FARMS.

At the recent session of the Territorial legislature an appropriation of $20,000 was made for this station for the biennial period. It is understood that this sum of $10,000 per year is to be used chiefly in the establishment and maintenance of demonstration farms. Three such farms have already been located and are in operation. On the windward side of Hawaii two demonstration farms have been located, one at Hilo and one at Glenwood. At Hilo the area at the disposal of the station is about 2 acres, while the farm at Glenwood occupies 15 acres. The small plat at Hilo is taken up at present with experiments on bananas and taro. The renewed interest which has been shown in bananas has made it desirable to get some reliable data on the proper planting distance for Bluefields bananas and on fertilizers and cultural methods for this crop under the climatic conditions at Hilo. There was formerly a somewhat extensive banana industry in Hilo, and it is hoped that this may be revived with proper encouragement.

The problems to be studied at Glenwood are peculiar to that locality, but any results which may be obtained by careful experiments there will apply to a large area of possible homestead land. Many attempts have been made in the past to raise various crops such as are used in diversified agriculture and also sugar cane on the peculiar soils of this region, but without satisfactory results. The rainfall is very high, the soils being saturated most of the time. Moreover, the underlying strata of the soil are apparently of entirely different nature from the upper 3 or 4 inches, and while easily tilled and apparently porous are nevertheless difficult of aeration. The usual experience of attempting to raise crops on this soil has been that while the first crop was satisfactory in quantity a decided falling off in the yield occurred in the second year and was more pronounced in any subsequent attempts at cultivation. It is necessary to determine what can be done in aerating this soil by different systems of plowing, including blasting with dynamite, fallowing, and burning the surface by means of log fires. Such burning of the soil in a few other localities in the Territory has given striking results in improving the physical structure of the soil and increasing the yields obtained. There is an encouraging local interest in solving these problems, and to this end $1,000 per year for a period of at least five years has been subscribed by private individuals and companies to supplement the Territorial funds in carrying on the experiments.

COOPERATIVE EXPERIMENTS.

During the year a number of cooperative experiments have been carried on by arrangements with private individuals and companies. These experiments have included attempts to determine whether pineapples may be improved in form by selection of suckers from plants which bear fruit of the most desirable form; also fertilizer experiments with taro and rice, methods of propagating and the cultural requirements of the yellow sweet potato of the mainland, and pruning experiments with cotton. It is still too early to feel sure of the results from the selection work with pineapples. In the cooperative fertilizer experiment with taro it is obvious that this plant, like rice, is benefited by allowing the soil to dry out and become aerated between crops, by applying all of the fertilizer before planting rather than after planting or in fractional doses, and by using sulphate of ammonia rather than nitrate of soda as a source of nitrogen. It has been found that the yellow sweet potato, known under various names on the mainland, may be made to yield a good quality of tubers in various localities in the Territory and that these tubers bring a high price (up to 8 cents per pound) when shipped to California during the season when mainland sweet potatoes are not to be had. The pruning experiments with cotton are only well under way. They are designed to test out on a large scale the results which have already been obtained on smaller areas upon the station grounds.

ENTOMOLOGICAL INVESTIGATIONS.

During the year the most important entomological occurrence in Hawaii was the discovery of the Mediterranean fruit fly. It is not certain when this pest first found its way into Hawaii, but, at any rate, the presence of the insect was not definitely known until this year. After its discovery it spread with remarkable rapidity, attacking peaches, all of the citrus fruits, mangoes, peppers, guavas, figs, and avocados. The occurrence of this pest in Hawaii led to the prompt establishment of a quarantine on the part of California against Hawaiian fruits, except pineapples and bananas. The last two fruits are the only ones which were already being shipped in large quantities to the mainland, but there is an increasing demand in California and elsewhere for avocados, mangoes, and also papayas. The outlet for these fruits is therefore completely closed for the present until some effective method of control can be devised. This station has taken part in devising such a plan. The essential features of the plan at present consist in the careful daily collection of all fallen fruit and the removal of such fruit by the official garbage collectors, followed by burning, or collection by hog raisers, who boil the fruit before feeding. The results of this campaign are already evident and it seems possible gradually to reduce the numbers of the fly by this same means if the proper cooperation of householders and all interested parties can be maintained.

The growing importance of corn and leguminous crops in the problem of securing more forage has led to the cultivation of greatly increased areas of these crops and has also directed attention to some of their insect pests. The entomologist gave particular attention during the year to the insect pests of legumes and corn. The most important pests of legumes are considered in this report, and those of corn are to be treated in a forthcoming bulletin of the station. In these investigations it has been found that in some localities plant lice are very effectively parasitized. By artificially distributing these parasites about 95 per cent of the plant lice were attacked and destroyed. It is hoped that these parasites will become of great value in checking the annual losses from plant lice. Some attention has been given to the possible control of the cotton bollworm by means of parasites. A parasite is already known in Hawaii which destroys from 5 to 10 per cent of the bollworms, but a more effective one must be secured if possible. The Cotton Growers' Association, recently organized, proposes to raise sufficient funds to obtain additional parasites from India and other places where this pest is native.

HORTICULTURAL INVESTIGATIONS.

One of the chief lines of study during the year was concerned with the avocado. A budding method has been perfected by means of which success is obtained on young trees in from 85 to 90 per cent of cases and on old trees, by the method of top-working, in from 50 to 75 per cent of cases. Moreover, a successful inarching method has been devised for rapidly testing out promising seedlings. A collection has been made, as complete as possible, of the types of avocados found in Hawaii and a system of classification and description is now being worked out. This fruit shows a great variety of forms, not only of shape, color, and flavor, but also in the relative proportion of pulp to seed and in the thickness of the rind.

The variation in the flavor, size, and shape of papaya fruits is almost unlimited. A part of this variation seems to be due to the crossings which have taken place between the different varieties or perhaps between species. The only practical method of propagating papayas is by means of seed. Obviously, therefore, in order to eliminate variation and establish varieties which will come true it is necessary in some manner to prevent too much crossing. In the work done on papayas at this station it has been found possible to propagate the fruit by the use of monœcious trees without the help of sterile male trees. If it should prove a practical matter to secure the desired flavor and other qualities by this method alone, it will thereby become possible to avoid the loss of space incident to the growing of a large number of male trees and the lack of uniformity which has hitherto occurred when dependence was placed on the fertilization of the pistils of one form of diœcious trees with the pollen of another form.

During the year the station has had an unusual number of requests for budwood of various fruit trees and for seedlings of these and various ornamentals. The requests of this sort from the War and Navy Departments have been the largest, and so far as possible the station has cooperated in furnishing material to improve the grounds of the newly established Army posts and naval stations. The larger part of the distribution of such material made by the station is directly along the lines of work now being carried on. An attempt is being made to reduce so far as possible the distribution of miscellaneous sorts in order that this may not interfere with the time of the members of the staff. Attention has previously been called to the fact that some of this work of distributing ornamentals and miscellaneous fruits and vegetables should be taken up on a commercial scale by some nurseryman.

CHEMICAL INVESTIGATIONS.

The investigation of manganese soils has been continued during the year. The results obtained in this work have added greatly to the knowledge of conditions which prevail in these soils and have helped to shape a practical policy of utilizing these soils, particularly in the pineapple districts. It may now be confidently asserted that highly manganiferous soils should be avoided in planting pineapples. This fruit is exceptionally sensitive to unfavorable soil conditions and can not be made to thrive on soils which contain from 4 to 5 per cent of manganese. A number of other crops are less sensitive to manganese and thrive fairly well on such soils. Among these may be mentioned sugar cane, corn, and cotton. If for any reason it is especially desired to grow pineapples on highly manganiferous soils, the best results can be obtained by planting the old stumps rather than the suckers and by fertilizing heavily with phosphates.

It appears more and more certain that pineapples do not require so much water as has sometimes been supposed; in fact, one of the most serious difficulties in the pineapple district of Wahiawa, where about 5,000 acres of pineapples are grown, is in securing the proper drainage of the soils. It has been necessary to plow the land in such a way as to obtain ditches with the proper grade to carry off the excess of water. Tiles for drainage are too expensive in Hawaii and they can not be thought of as a practical treatment of the drainage problem at present. It is of great importance that the cultivation of pineapple soils should be avoided when these soils are too wet, otherwise they will become so badly puddled as to make proper drainage impossible. There are locations, particularly on Maui and Kauai, where the soils are not so easily puddled and where drainage is naturally accomplished in a satisfactory way, even in the presence of a larger rainfall than occurs in the Wahiawa section. On properly tilled soils the experiments thus far carried on with fertilizers show that the best combination for pineapples is superphosphate, sulphate of potash, and ammonium sulphate.

The fertilizer experiments with rice have been continued on the same plats and along the same line as was reported last year. The results secured on the two crops during the year were strictly in harmony with those previously obtained. It is evident that all the fertilizer should be applied to rice before planting and that nitrogen should be supplied in the organic form or in the form of ammonia rather than as nitrate.

In the fertilizer experiments with cotton a large increase in yield was brought about by a proper combination of different elements of plant food. The results as a whole, however, show that on the soils thus far used for growing cotton, phosphoric acid is the element which is most needed and the one which produces the most striking increase in yield.

Data are gradually being accumulated for a general classification of Hawaiian soils. It is impossible to classify them according to the schemes ordinarily adopted on the mainland, for the reason that physical and chemical properties of Hawaiian soils are so peculiar that the soils do not readily fall into mainland categories of classification. Among some of the more strikingly peculiar soils it is only necessary to mention those which contain from 8 to 10 per cent of manganese and an area which was recently found to contain 20 per cent of titanium.

The work in prospect for the coming year includes a study of sisal waste, the determination of the amount of oil in the kukui nut and practical methods for extracting it, a study of pineapple stumps with reference to their possible use in starch manufacture, a study of the prevalence of chlorin and sulphur in plants, and tests of the effect of heat on soils which show poor drainage.

COTTON.

Interest in cotton in Hawaii continues to increase, and the results thus far obtained justify the much larger plantings which have already been made. It was necessary in the first place to carry on much experimental work to determine under what conditions cotton would thrive best and the cultural methods which must be adopted to insure success. All cotton plantings in the Territory at low elevations or in localities protected against the trade wind have shown large yields of lint of good quality. The returns coming in from the early crop show yields of from 400 to 600 pounds of lint per acre, and also indicate that a practical method of holding the bollworm injury within bounds is now in operation.

One of the unsuspected results obtained in the cotton experiments of the station is the proof of the peculiar sensitiveness of cotton to even moderately cool weather. At low altitudes the temperature rarely falls as low as 60° F. At such a temperature, however, if accompanied by moderate trade winds, the leaves of cotton may be browned and curled as if frostbitten. While the trade winds are never strong as compared with the high winds which occasionally prevail on the mainland, yet their constant blowing from one direction largely prevents the setting of the bolls on the outside row of cotton toward the northeast. In isolated plants the windward side may be without bolls while the leeward side of the same plant is heavily loaded. The beneficial effect of windbreaks is very pronounced in all cotton fields exposed directly to the trade winds. In protected localities, however, the growth, yield, and quality are all that can be desired.

A number of plantings have been made in coral sand at sea level, even on the windward side of the islands, and in all of these plantings the cotton has grown and borne well. It appears that no injury is produced even if the roots reach down into the salt water. Heavily bearing plants may be seen in sand not over 2 feet above sea level and within 10 feet of the water's edge. In Hawaii, as elsewhere, it is evident that cotton can not obtain too much sun nor too much heat, but that too much rain may be injurious.

Success with cotton in Hawaii is not determined by altitude alone, for excellent fields are to be seen at altitudes of from 700 to 1,600 feet. These, however, are located in sections where the trade wind is broken by mountains. It is impossible to give with certainty the rainfall which cotton will endure, but in soils retentive of moisture a good crop has been made with 15 inches of rain, and the other limit of variation would seem to be about 80 inches. With too much rainfall all the varieties of cotton with which the station has experimented grow too tall, thus making picking difficult and increasing the cost of harvesting.

The practical control of the bollworm may be accomplished by pruning back the whole field at the close of each picking season and burning all the rubbish promptly. The larvæ and pupæ of the bollworm are found in the infested bolls and are destroyed by burning. Pruning interrupts the crop of bolls as completely as a new planting where the cotton is treated as an annual. It is necessary to prune not only to keep down damage from bollworms but also to hold the plants in proper form; otherwise cotton grown as a perennial attains a size and shape which renders picking difficult. By proper pruning and pinching the terminal buds, it has been found possible to increase greatly the number of lateral branches and to hold the plants within a proper size. Growth from pruned plants is considerably more rapid than from seed, and the yield of such plants is larger than from seedlings the first year. It is barely possible, therefore, that in the extreme southern portion of the cotton belt of the South the same method might be used, provided that the pruning is done low and the stumps protected from the winter frosts by mulching. Upland cotton does not ratoon as promptly, however, as Caravonica and Sea Island.

The danger of hybridization if different cottons are grown in close proximity is apparently greater than has usually been stated. On the station grounds each variety was grown in an isolated spot, at least 300 yards from any other variety. In this way it was possible to make seed selections from year to year with reasonable assurance of success and purity of strain. A peculiar type of Caravonica cotton has developed in which the lint is unusually harsh and strong. This seems to be particularly well suited for mixing with woolen goods, and reports received on samples of the lint indicate that it will be readily bought for that purpose. The latest quotations on lint of cotton samples, which the station has submitted to buyers and cotton graders, are 40 cents for Sea Island, 28 cents for Sunflower, and 25 cents for Caravonica.

MISCELLANEOUS.

The results from the introduction of Japanese rices have not been completely satisfactory. Samples of milled rice submitted to various individuals supposed to be judges of the milled product have brought various opinions which are not quite in harmony. A few have stated that rice grown in Hawaii from seed imported from Japan is equal in every way to imported Japanese rice. Others have rated it as inferior to the imported rice or as differing from it in certain culinary or other properties which are hard to define, and on which the different individuals to whom the rice was submitted did not agree. The yield of the Japanese rices is satisfactory. There is a general depression in the rice industry in Hawaii, largely due to the preference of the Japanese for the rice imported directly from Japan, and to the further fact that only Chinese labor is available for work in the rice fields and that this labor is scarce and demands an increasing wage. These facts, combined with the high rentals (from $25 to $40 per acre annually) which the rice growers pay for their land, make it difficult to obtain a profit from growing rice.

As a result of experiments with broom corn it has been found that a good quality of brush can be produced in Hawaii, somewhat superior to that grown in California and nearly equal to that obtained in the Central States. A broom factory has been established which can use more brush than is now produced in Hawaii. A number of rice growers and others are beginning to plant this crop in order to supply the local demand. Little difficulty has been experienced in growing broom corn, except in the occasional attacks of plant lice.

There is an increasing demand for leguminous crops for a great variety of purposes. The sugar planters are looking for suitable legumes to grow between the rows of cane for controlling weeds and as a source of nitrogen. Dairymen and ranchers have use for all of the leguminous crops which they can produce for feeding green. The pineapple growers need a suitable legume as a rotation crop and orchardists as a cover crop. For dairy purposes alfalfa, jack beans, and cowpeas are perhaps the best legumes. In some of the pineapple districts pigeon peas have proved superior to all other legumes as a rotation crop. The station is testing all legumes which can be considered as suitable for Hawaii in various locations on the different islands, and the results of the experiments are quickly adopted by the planters and farmers.

Corn is not produced in sufficient quantities to supply the local demand. On one of the larger ranches about 1,400 acres of corn were grown this year, with an average yield of about 35 bushels per acre. All this corn, however, is used for feeding on the ranch. Smaller plantings are being made on other ranches with satisfactory results, but without adding any to the supply of corn on the market, since it is all used in feeding beef cattle and horses. A number of farmers have engaged in corn raising to supply corn for the horses and mules of neighboring plantations. The only serious difficulty in raising corn in Hawaii is of an entomological nature. A bulletin on corn insects was prepared during the year. A variety of flint corn known as Yellow Creole and recommended as being resistant to corn insects in Louisiana is being tested out, with promising results.

During the year the following publications were issued by the station:

Bulletin No. 21. A Study of the Composition of the Rice Plant.
Bulletin No. 22. Insects Attacking the Sweet Potato in Hawaii.
Bulletin No. 23. Leguminous Crops for Hawaii.
Bulletin No. 24. The Assimilation of Nitrogen by Rice.
Bulletin No. 25. The Avocado in Hawaii.
Press Bulletin No. 27. Use of Insecticides in Hawaii.
Press Bulletin No. 28. Peanuts in Hawaii.
Press Bulletin No. 29. The Management of Pineapple Soils.
Press Bulletin No. 30. Killing Weeds with Arsenite of Soda.
Pamphlet on Taro, in Hawaiian.
Pamphlet on Bananas, in Hawaiian and Portuguese.
Pamphlet on Grapes, in Portuguese.
Pamphlet on the Grazing Industry, in English.

REPORT OF THE ENTOMOLOGIST.

By D. T. Fullaway.

This report covers the periods from July 1 to August 15 and from January 1 to May 15. The entomologist was absent on leave from August 16 to December 31, and on May 16 was transferred to the experiment station at Guam. The routine work of the office, however, was adequately attended to throughout the year and the collections were maintained and much material added. Numerous inquiries regarding destructive insects and remedies therefor were answered by letter or given personal attention.

The investigation of the insects affecting cereal crops, begun the previous year, was continued, and a part of the results are to appear in a later bulletin of the station.

The growing interest in leguminous crops for fodder or soil improvement induced the entomologist to give some attention to the destructive insects of the commoner legumes. The following notes cover observations on the insects attacking the pigeon pea (*Cajanus indicus*), cowpea (*Vigna catjang*), jack bean (*Canavalia ensiformis*), velvet bean (*Mucuna pruriens*), soy bean (*Glycine hispida*), peanut (*Arachis hypogæa*), sweet clover (*Melilotus officinalis*), and alfalfa (*Medicago sativa*). More attention was given to pigeon pea than to the other mentioned crops and, while the list is admittedly not complete for all of these plants, it indicates in a general way what the agriculturist has to contend with in the cultivation of legumes.

NOTES ON INSECTS ATTACKING LEGUMINOUS CROPS.

Leguminous crops are subject to attacks of cutworms and army worms, especially in the winter and spring or on irrigated land. Large fields of alfalfa are sometimes devastated by the army worm, *Heliophila unipuncta*, before it can be brought under control by its natural enemies. Extensive plantings of jack beans have been laid waste by another common army worm, *Spodoptera mauritia* (fig. 1). Swezey records *Spodoptera exigua* from peas and beans, and the writer bred *Heliothis obsoleta* on pigeon pea. One enterprising farmer checked an attack of army worms by flooding his fields. The caterpillars, floating on the water or caught in the meshes of stranded vegetation, were greedily devoured by mynah birds. Cutworms and army worms are usually kept in check by their parasites—the tachinid flies, *Frontina archippivora* and *Cheatogadia monticola*, the ichneumonid, *Ichneumon koebeli*, and birds. It is, however, sometimes advisable to protect fields from cutworms by spreading out, near the plants, poisoned bait, consisting of arsenic and bran, with a small amount of sugar or molasses to moisten the mixture.

The foliage of legumes is often badly eaten by certain leaf-rollers, *Omiodes monogona* (fig. 2), *Amorbia emigratella* (fig. 3) and *Archips postvittanus*, and by the looper, *Plusia chalcites*, but the damage they inflict is apparently not great except in the case of *Omiodes monogona*, which, so far as is known, feeds exclusively on legumes. It, however, is subject in turn to the attacks of parasites which keep it fairly well in check. *Limnerium blackburni* has been bred from it by Mr. Swezey, and the writer bred *Chalcis obscurata* from the pupæ.

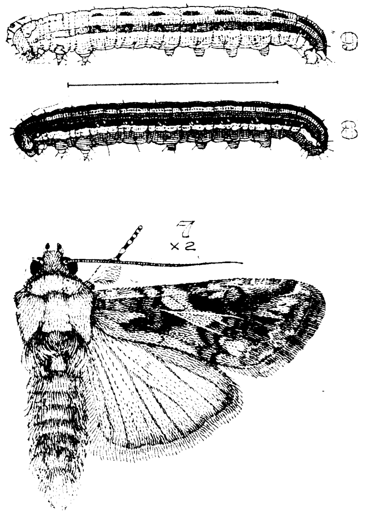

FIG. 1.—*Spodoptera mauritia*: Larva and adult.

Plant-lice or aphids are usually found on cultivated legumes and are likely to affect the growth seriously, especially in the winter months. Some legumes seem to suffer more than others, notably the cowpea, which sometimes becomes so badly infested that it is impossible to get a good stand. The species which attacks legumes is thought to be *Aphis gossypii*. When the infestation is bad, the dark form, ranging from dull purplish-black to shining piceous black, prevails. It is often necessary to spray legumes threatened with aphid injury with tobacco decoctions and nicotine solutions, which are fairly cheap and effective agents to use in such cases. Aphids are fairly well kept in check most of the time by ladybird or coccinellid beetles, of which there are numerous introduced species present. The larvæ of the syrphid fly, *Xanthogramma grandicornis*, and of the agromyzid, *Leucopis nigricornis*, also prey on aphids and are usually found where aphids are abundant.

The common representative of the scale insects (Coccidæ) found on legumes is the cottony cushion or fluted scale, *Icerya purchasi*, which, while normally controlled by *Novius cardinalis*, sometimes becomes very abundant and does considerable damage before the ladybirds become numerous enough to clean it out. Pigeon pea and peanuts are usually more badly infested than other legumes. Cutting and destroying all badly infested branches as soon as noticed is recommended. When abundant the scale insects are usually massed together on the stems and very little work is involved in thus getting rid of them. Mealy bugs, embracing several species, infest legumes, notably *Pseudococcus longispinus*, *P. citri*, *P. virgatus*, and *P. fiamentosus*, but do little apparent damage and are usually controlled by their parasites and predators. The first three species have been noticed on pigeon pea and the last more especially on clover. The flat scale, *Saissetia oleæ*, is common on pigeon pea and crotalaria.

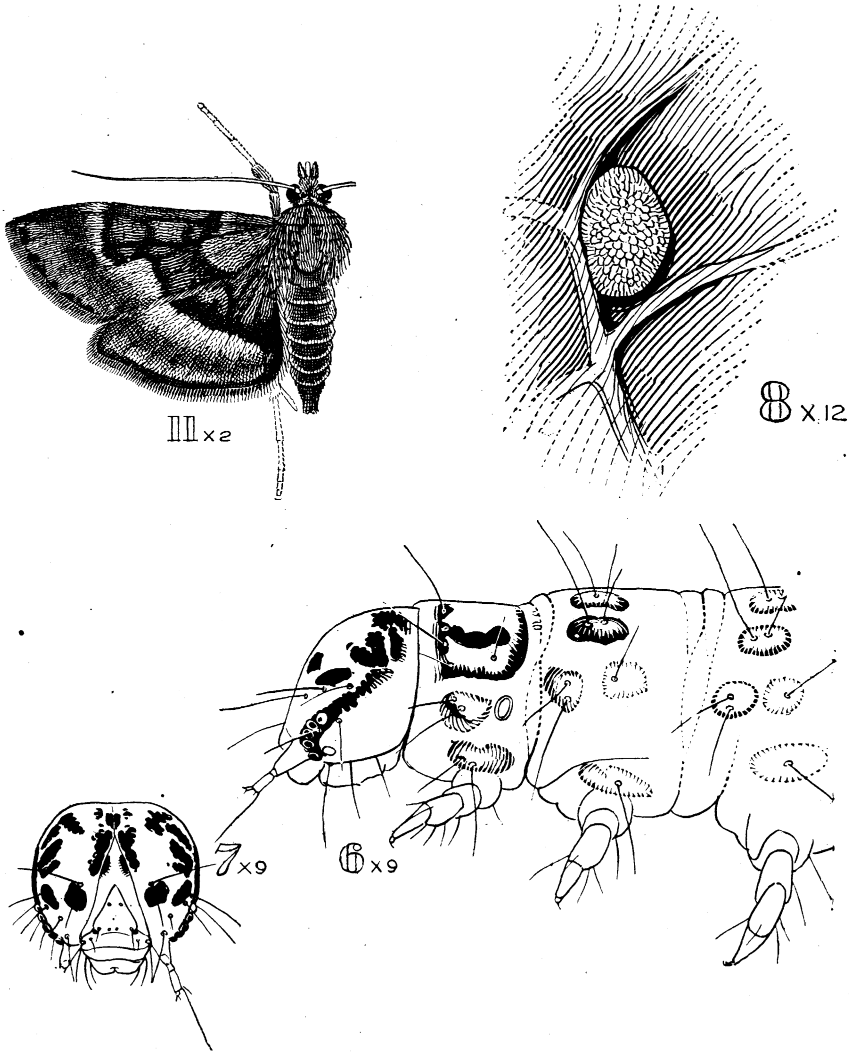

FIG. 2.—*Omiodes monogona:* Adult, egg, and larva.

The leaves of most of the cultivated legumes and some other plants as well are mined by the larva of a small agromyzid fly, determined by the late D. W. Coquillett, of the Department of Agriculture at Washington, as *Agromyza diminuta.* The wandering track of the miner in the mesophyll is indicated by a rather broad line of transparent green which contrasts boldly with the darker shade of the leaf. The foliage is often badly shattered, and if the mining is extensive, one surface of the leaf will usually split when the leaves become dry and brittle. This miner, however, will probably never be a serious pest, as it is effectively parasitized by the eulophids, *Omphale metallicus* and *Pediobius* sp. The adult fly is the pretty little black and yellow two-winged insect often seen hovering about the foliage of legumes. It has been bred from leaves of cabbage, geranium, and

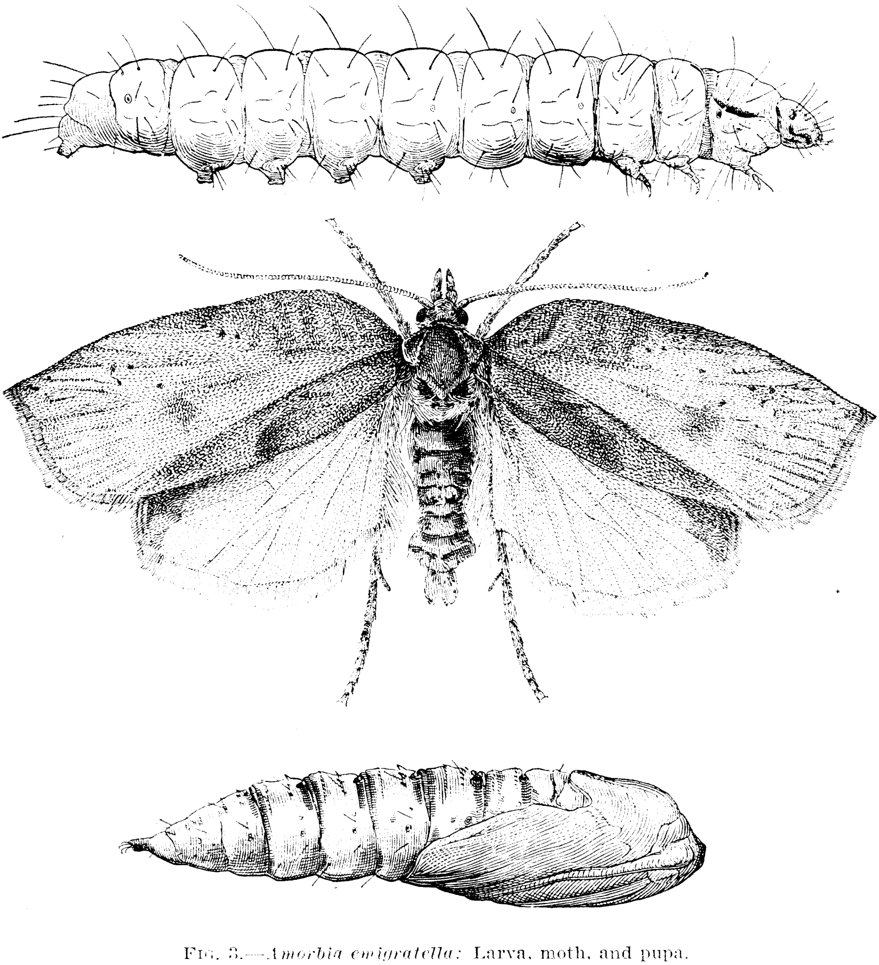

FIG. 3.—*Amorbia emigratella:* Larva, moth, and pupa.

nasturtium as well as from the following legumes: Jack beans, cowpeas, alfalfa, and clover. The larva, when mature, leaves the leaf by breaking through the epidermis and enters the ground to pupate.

Probably the most injurious insect attacking legumes is the one designated the bean pod borer, the larva or caterpillar of the common blue or hairstreak butterfly *Lycæna bœtica*. This is a widely distributed pest, not, however, found in America. Its habitat as given by Meyrick is western France (an occasional emigrant to England), southern Europe, central and southern Asia, Africa, Australia, and the Pacific Islands. It attacks the pods of various legumes, devouring the growing seeds. The pigeon pea, according to my observation, is more severely attacked than other legumes, but the crotalarias and garden peas and beans are usually infested. I have also found the eggs on jack beans and cowpeas. The following is an account of its life history:

The eggs are laid singly, on the outer parts of the flower (sepals and bracts), on the leaves, and on the stems. They are pale green when fresh, depressed spheroidal, 0.5 millimeter in diameter, 0.27 millimeter high; openly reticulate, the network formed by well-developed ridges; tuberculate at the angles of intersection. The reticulation is more closely drawn around the micropyle, which lies in a shallow depression. The base is rather flat and rather faintly sculptured.

The larva emerges through a hole made in the top and at the time of hatching is about 1 millimeter long, body yellowish green, head black, cervical shield conspicuous, transversely rhomboidal, fuscous, anal shield black, more or less cylindrical, tubercles black, minute, each with a seta, arranged in longitudinal rows, 1 close to dorsal line and more or less posterior in the segment, 2 a little more removed and anterior, larger than 1, 3 above the spiracle, 4 and 5 below, 4 anterior, 5 posterior in the segment, 6 and 7 beneath, hairs longer laterally and caudally. The larva moults three times during the course of its growth. When full grown it is about 14 millimeters long, 4.5 millimeters wide, onisciform in shape, the segmentation distinct. The head is small, about 1 millimeter wide, retractile and usually hidden beneath the first segment, rounder in front, slightly depressed, testaceous, lower margin of ocelli broadly, upper margin narrowly, labrum, anterior margin of interlobular area and borders of lobes entirely black. The body is plump, light green, with the following claret markings, the colors varying greatly in intensity; dorsal line, beginning at anterior margin of third segment and extending to tip, a deep claret, oblique claret suffusion on each segment, midway between dorsal line and spiracles, pale claret suffusion laterally along spiracular line. Thickly covered with irregular blackish and whitish tubercles bearing short brownish hairs; more closely crowded on eleventh and twelfth segments. Legs brownish with black tips: spines on prolegs claret colored, lateral line and under side of body very pale green. Three last segments depressed, linguiform. Hairs longer on first and second segments and under side of body. The length of the larval stage is about 18 days.

The pupa is about 10 mm. long and of the usual lycænid form. Outline from above irregularly oval, greatest width 4.5 mm., at fourth abdominal segment. Dorsum rounded, venter more or less flat, thorax gibbous, a large well-formed gibbosity dorsally and smaller protuberance laterally. Cephalic margin truncate, slight constriction at first abdominal segment, body gradually contracting beyond fourth segment. Luteo-testaceous and speckled with fuscus black, also black markings as follows: A large one on dorsal line of head, several subdorsally and laterally on thorax, an irregular double line on abdomen above spiracles, continued on venter to sixth segment, dorsal claret line from anterior margin of third abdominal segment to posterior margin of seventh. The spiracles are small, narrowly elliptical, margins black. Wing and antennal cases reaching posterior margin ot fifth abdominal segment, the former broadly rectangular. Short capitate hairs on head. Cremaster inconspicuous. The length of the pupal stage is 11 to 12 days.

Moth.—"Length 26–30 mm. Wings fuscous, in ♂ suffused with purple-blue except on termen, in ♀ on basal half only; hind wings with long linear terminal projection on 2, and a blackish subterminal spot on each side of it. Wings beneath pale brownish, with irregular partly connected white striæ; hind wings with white posterior fascia, and two black partly orange-edged spots, marked with pale metallic green-blue, before termen above tornus." [1]

The dry pods and seeds of legumes are attacked in storehouses and somewhat in the field by certain insects which habitually feed on stored products, notably bruchid weevils. Five species of this family have become established here. *Bruchis chinensis* and *B. prosopis* have bred from seeds of the pigeon pea, *B. chinensis* from seeds of the cowpea, and *B. prosopis* and *Caryoborus gonagra* from seeds of keawe (*Prosopis juliflora*). The prinid beetle *Catorama mexicana* has been bred from seed of the velvet bean and the common coffee bean-weevil (*Aræcerus fasciculatus*) from pigeon pea seed stored and in the field. (Fig. 4.)

The following minor pests have been observed: A thrips determined by Mr. E. M. Ehrhorn as *Trichothrips nigricans* is abundant in the blossoms of pigeon pea. *Xiphidium varipenne* probably sometimes feeds on legumes, but is largely carnivorous in habit. A red spider (*Tetranychus* sp.) has been noticed on the foliage. The broken stems are bored by bostrychids.

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[1] Meyrick. Handbook of British Lepidoptera. London, 1895, p. 347.

In connection with the work outlined above some observations were made on the capsid bug *Hyalopeplus pellucidus*, which is commonly found on pigeon pea as well as on many other economic plants, notably cotton and hibiscus. It has usually been thought that this insect is at times predaceous, and having it on the authority of the late Mr. Kirkaldy and others, the writer so described it in a bulletin on cotton insects published several years ago.[1] But after taking the greatest pains to discover any predatory inclinations, he is inclined to think it nourishes itself entirely on plant juices. It has repeatedly been observed in all stages feeding on plants.

Kirkaldy[2] describes the ultimate and penultimate nymphal instars, but nothing is said of the egg or earlier stages. Several gravid females captured in the field and confined in breeding jars oviposited a few days later and the process of egg laying was carefully noted. The eggs are inserted singly in the stems or buds, one female laying probably 15 or 20. They are about 1.4 mm. long, smooth, pearly white, and flattened cylindrical, slightly curved, with a spur outwardly on lower edge, which forms the scar. The egg stage occupies approximately 10 days. There are supposedly five nymphal instars as in other bugs, but only four were observed by the writer, the first apparently being missed. There is little difference in the earlier stages from those described by Kirkaldy, except in the shape of the body and the comparative length of body, beak, and antennæ. In the second instar the body is 1.5 mm. long, the antennæ 1.75 mm., second and fourth antennal joints subequal, third nearly 2, and the second 2½ times the first. The labium reaches nearly to the apex of the body which is covered with long fuscous yellowish pile. The

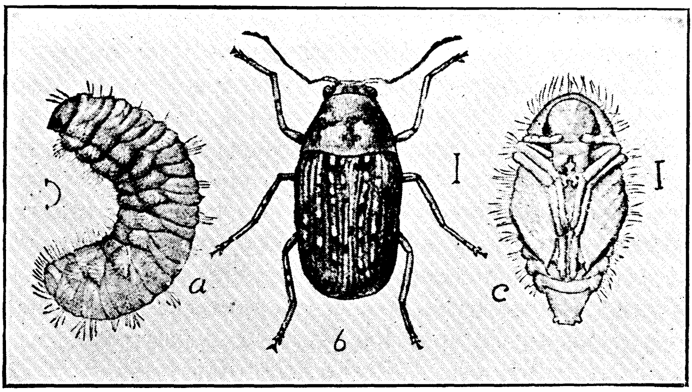

FIG. 4.—*Aræcerus fasciculatus:* Larva, beetle, and pupa.

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[1] Hawaii Sta. Bul. 18, p. 25.

[2] Proc. Hawaiian Ent. Soc., 1 (1907), pt. 4, p. 159.

pronotum is a little longer than the head and a little less than its apical width. The hind margin is subequal to the apical margin; scutellum indistinct.

In the third instar the body is 2.5 to 3 mm. long, the antennæ 2.5 mm., the relative length of joints very much as in later stages. The labium reaches the apex of the fourth sternite. In this and the preceding stage the markings are more extensive than indicated by Kirkaldy. The purplish-red or sanguineous medium percurrent or laterally sinuate lines on head reach slightly beyond the thorax, and on the abdomen on each side are five more or less distinct percurrent lines of sanguineous spots reaching to the apex, where they are more pronounced than in front. In this stage the wing bugs appear. The total length of nymphal life is 14 days.

THE MEDITERRANEAN FRUIT FLY.

The recently introduced Mediterranean fruit fly (*Ceratitis capitata*), which was first noticed in the summer of 1910, is spreading rapidly on Oahu and gives every promise of becoming a serious fruit pest here as elsewhere. It has been bred so far from oranges, limes, pomelos, peaches, mangoes, guavas, and peppers. Citrus fruits and peaches around Honolulu seem to be generally infested. The insect, which is probably a native of Africa, but now widely distributed by commercial operations, resembles in a general way the melon fly, but is much handsomer in appearance. Its habits are very similar to those of the melon fly, the eggs being laid beneath the surface of fruits by means of the sting-like ovipositor. Infested fruits often show discolored spots on the surface. The maggots hatching from the eggs develop in the interior of the fruit, which gradually becomes putrid. Fruit infested on the tree usually falls early to the ground and the larvæ when full grown leave the fruit and enter the soil to pupate. The life cycle is said to cover about one month.

Little can be suggested in the way of remedial measures, as the fly reproduces itself so rapidly and so abundantly that, in countries where conditions are less favorable for its multiplication than they are in Hawaii, it is impossible to prevent great damage by the fly to the fruit crops which it infests. In South Africa it is partially controlled by the timely application of a light sprinkling of poisoned bait, consisting of 2 pounds of arsenate of lead and 25 pounds of sugar to 40 gallons of water, on the trees. In Hawaii, however, as pointed out by Dr. Perkins, the hive bee must be taken into consideration, many of which would also be killed by the poison, especially at such times as the algaroba and other flowers visited by the bees are out of bloom.

REPORT OF THE HORTICULTURIST.

By J. E. Higgins.

One of the chief lines of work that has occupied the attention of the horticultural department during the year has been on the avocado. Among other aspects of the subject, special attention has been paid to propagation, spraying for the control of a fungus disease and for a caterpillar, and also the study of varieties.

AVOCADO INVESTIGATIONS.

Much attention has been given to the propagation of the avocado by budding, both at the station and elsewhere. Investigations have now been carried far enough so that methods of budding have been devised which are quite satisfactory. Some of the difficulties which have been encountered have been in the securing of good bud wood and the starting of buds into growth. Some old trees that are doing well in fruit production fail to produce a reasonable number of good buds. In the case of these it is sometimes necessary to prune a part of the tree rather severely to induce a growth of suitable bud wood. It has been found best to force newly set buds into growth by the incomplete girdling of the branch about 6 inches above the bud. It has not been very satisfactory to lop the avocado trees, as has been done with citrus. It has also been found to be an advantage to cover the entire bud with a wax bandage at the time of budding. With such precautions and working with good stocks, from 75 to 90 per cent of the buds may be expected to grow.

The spraying experiments, which have been carried on largely by Mr. Hunn, have been designed to determine the best methods for the control of a fungus disease which has been called "rusty blight" because of its effect upon the foliage, and also for the control of a leaf-folding caterpillar, *Amorbia emigratella.* The effect of some of these sprays is also being noted upon the avocado mealy bug, *Pseudococcus nipæ.* The four sprays used have been Bordeaux mixture and arsenate of lead, Bordeaux mixture and lime resin, self-boiled lime-sulphur and arsenate of lead, and a brand of commercial lime-sulphur and arsenate of lead, thus using a combined insecticide and fungicide.

Mr. Hunn has made an extensive study of the varieties of avocados growing in and about Honolulu. Between 65 and 70 varieties have been carefully studied and described. A number of these have already been budded into the trees in the avocado orchard. This orchard is making normal growth, and a few of the trees are coming into bearing. These phases of the avocado work, as well as others, have been reported upon quite fully in a bulletin recently issued upon the avocado in Hawaii.[1]

Detailed outlines have been devised by Mr. Hunn for the description of varieties of avocado, papaya, mango, and hibiscus.

PAPAYA INVESTIGATIONS.

BREEDING.

The papaya investigations have been continued through the year. The work has included breeding, pruning, thinning, and shipping, and has been carried out by Mr. Valentine S. Holt, assistant in horticulture. The ultimate aim of a part of this undertaking is to work out methods for the breeding of varieties of desired qualities that can be depended upon to reproduce themselves with reasonable accuracy from seeds. It will be understood that there is no means available for the propagation of the papaya by asexual parts, as cuttings, buds, scions, etc., hence seed varieties must be established by methods probably similar to those used in breeding varieties of vegetables and flowers which are not propagated by budding and grafting.

The report for the year 1910 indicates the progress of the work to that date. It may be recalled that attention was then directed to the two most distinct forms of the papaya—the diœcious and the monœcious, with many apparently intermediate forms. Before entering upon a discussion it may be well to review this situation and note the significance of certain terms which have been adopted to designate the plants and flowers which enter into the work. Plate I shows the pistillate tree and flower representing the female element of the diœcious type. This diœcious type is the best-known form of the papaya. This pistillate tree, as is well known, produces the fruit. Plate II, figure 1, shows the staminate tree and flower of this diœcious type and represents the male element. This tree also produces occasionally a flower containing both stamens and pistils, and therefore capable of producing fruit. These hermaphrodite flowers, however, are frequently distorted, and most staminate trees fail to produce them. Plate II, figure 2, shows a tree and also a larger view of the flower of the monœcious type. It will be seen that the stamens are to be found attached to the inner walls of the corolla and quite close to the stigma.

Bearing in mind these distinctions, it may be recalled that in the last annual report a suggestion was then offered to the effect that it would probably be well to discontinue the use of the diœcious type,

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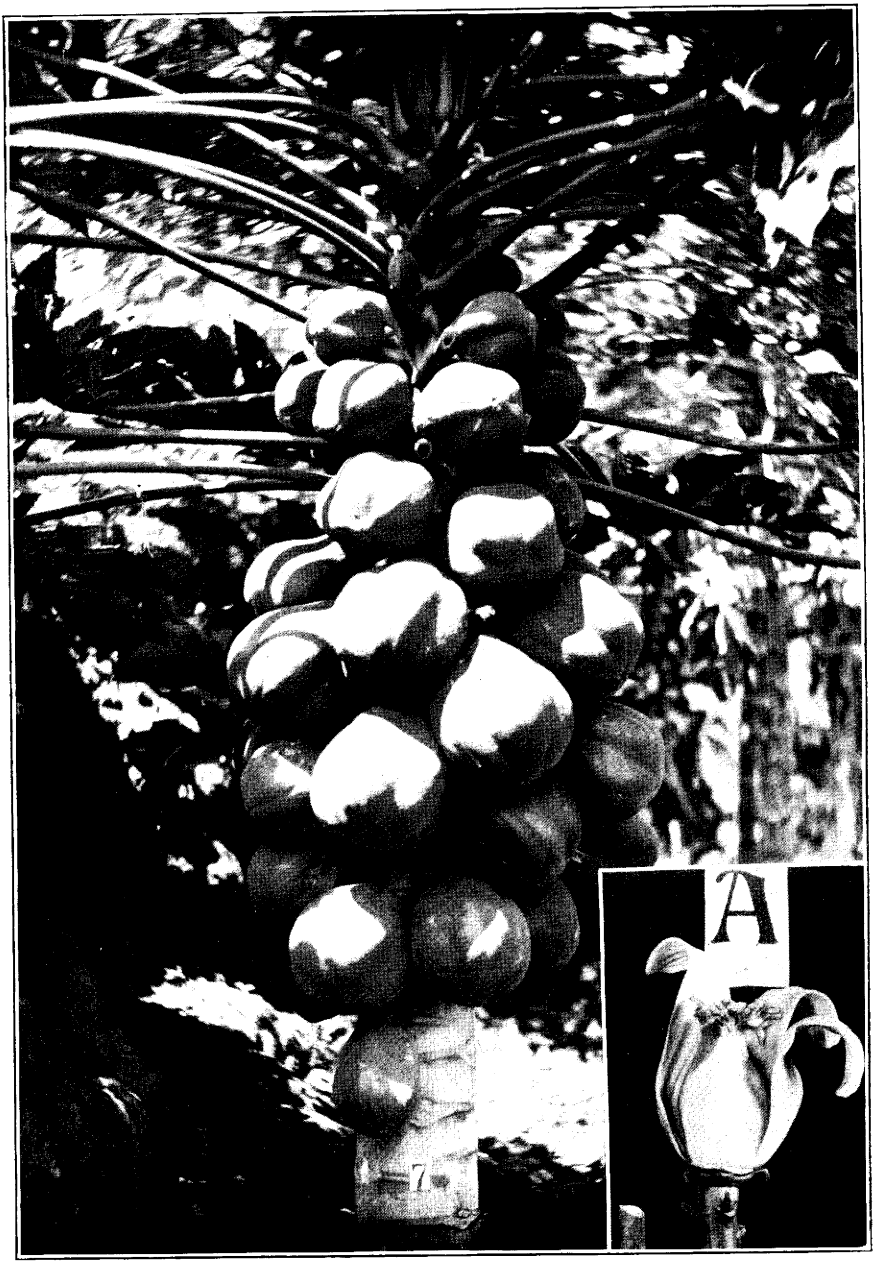
[1] Hawaii Sta. Bul. 25.



Pistillate Papaya Tree and Flower of the Diœcious Type.

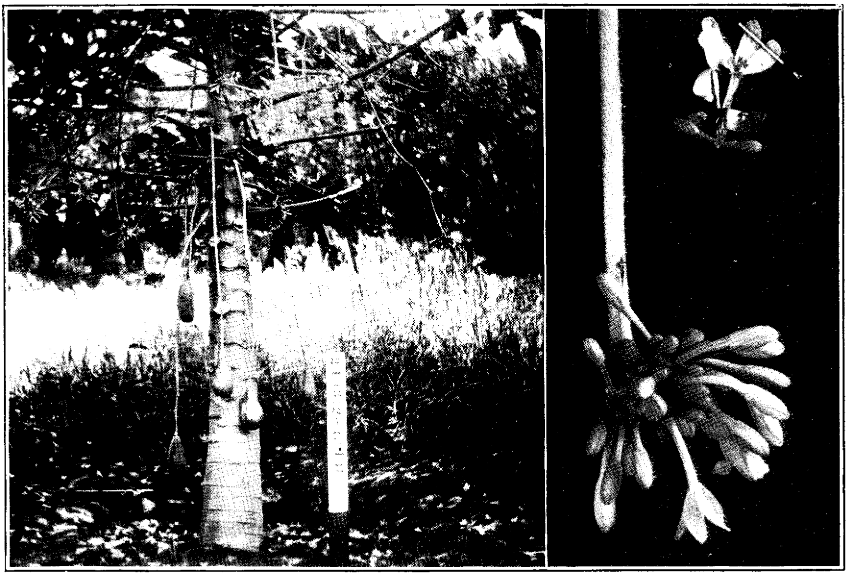


FIG. 1.—STAMINATE PAPAYA TREE AND FLOWER OF THE DIŒCIOUS TYPE.

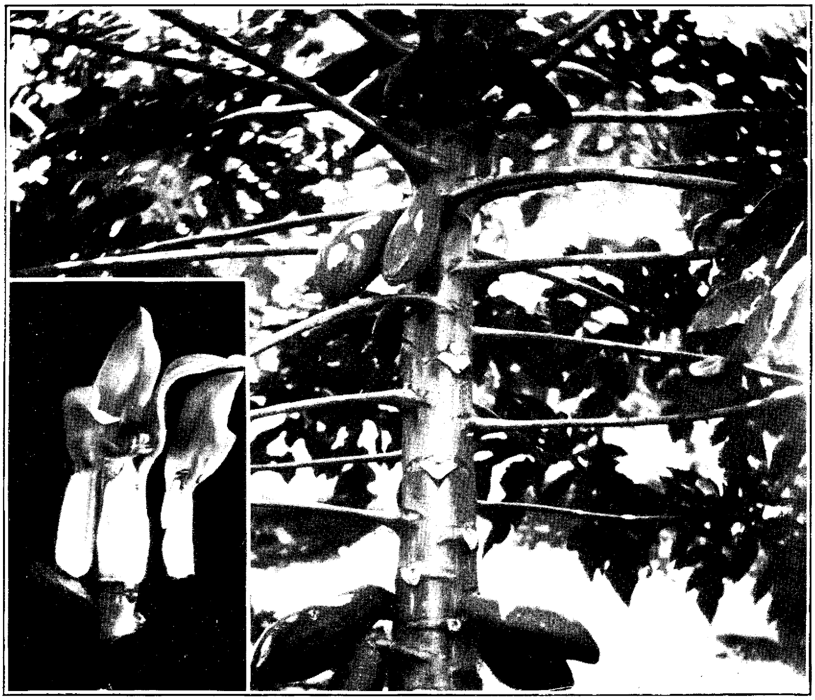


FIG. 2.—PAPAYA TREE AND PERFECT FLOWER OF THE MONŒCIOUS TYPE.

except, possibly, in combining it with the monœcious, because of the unknown and probably unknowable characters of the staminate plant. But some of the papayas of the diœcious type have certain desirable characters which it would be an advantage to combine with a monœcious variety. This opens the whole question as to the possibilities of close and cross pollination in the papaya. In order to test this matter, 16 different possible combinations of pollen and stigma were tested, and some light has been obtained on the subject. These possible cross and self fertilizations were as follows:

(S)[1] 1. Perfect monœcious flower with its own pollen.

(U) 2. Perfect monœcious flower with pollen from a staminate flower from the same cluster.

(U) 3. Perfect monœcious flower with pollen from a staminate flower of another cluster on the same tree.

(S) 4. Perfect monœcious flower with pollen from a perfect flower on another monœcious individual.

(U) 5. Perfect monœcious flower with pollen from a staminate flower of another monœcious individual.

(S) 6. Perfect monœcious flower with pollen from a perfect flower on the so-called "male tree."

(U) 7. Perfect monœcious flower with pollen from a staminate male flower on the so-called "male tree."

(S) 8. Pistillate (diœcious) flower with pollen from a perfect flower of monœcious type.

(U) 9. Pistillate (diœcious) flower with pollen from a staminate monœcious.

(S) 10. Pistillate (diœcious) flower with pollen from a staminate tree ("male").

(U) 11. Pistillate (diœcious) flower with pollen from a perfect (hermaphrodite) flower occasionally found on the so-called "male tree."

(S) 12. Perfect or hermaphrodite flower on the male tree with pollen from a perfect flower of the monœcious type.

(U) 13. Perfect or hermaphrodite flower on the male tree with pollen from a staminate flower of the monœcious type.

(S) 14. Perfect or hermaphrodite flower on the male tree with pollen from the staminate flower from the "male tree."

(S) 15. Perfect or hermaphrodite flower on the so-called "male tree," with its own pollen (hand pollinated).

(S) 16. Perfect or hermaphrodite flower on the so-called "male tree," with its own pollen (sealed in sack but not hand pollinated).

Several questions are involved in each of these pollinations. Take, for example, the eighth pollination, or that of a pistillate (diœcious) flower with pollen from a perfect flower of the monœcious type, which seemed perhaps the most promising means of combining any desirable character of the diœcious papaya with the monœcious, and out of this pollination will arise, among others, the following questions:

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[1] (S) and (U) refer to successful and unsuccessful crossing.

(1) Is it possible to make this cross?

(2) If this cross is possible, what will be the result in the sex of the progeny? Will there be a certain number of staminate trees and also pistillate and monœcious, or will some of the characters of the diœcious tree and some of those of the monœcious be combined in the offspring?

(3) To what degree will the characters of the female parent be reproduced in the monœcious offspring?

(4) Will it be possible by close pollination to preserve in future generations the monœcious character of certain members of the first generation of offspring if such appear? It will be remembered that the aim is to get back in breeding, as in commercial culture, to the monœcious type.

The work has already gone far enough to give definite answer to some of these questions and some light has been thrown upon others. For example, it can be stated definitely that the first question can be answered in the affirmative. It is perfectly possible to fertilize the stigma of a pistillate flower with pollen from a perfect flower of the monœcious type. Some light has been thrown upon the second question, but from its very nature it would be necessary to conduct a large number of tests extending over several years in order to establish any law governing the proportion of male and female and monœcious types resulting from such crosses. One year is a short time within which to get figures on this question. The striking fact, however, is that in the case of the eighth type of cross the resultants have shown a considerable proportion of monœcious individuals. Some of these resultants are intermediate in certain characters. While they produce flowers possessing both stamens and pistils which mature fruit, the stamens are less definitely located than in the case of the plant which we regard as the normal monœcious type. Plate III, figure 1, illustrates this condition. At "D" may be seen two flowers just beginning to develop into fruit. The one on the right has the stamens placed in the normal manner in the throat of the corolla to which they are attached. The upright one has dropped its petals, but the stamens may be seen still attached to the disk at the base of the ovary. This particular cluster of flowers came from a plant of unknown parentage, but illustrates the meaning of the statement that this flower and fruit are unlike the ordinary monœcious in form. The stamens are variously placed, in some cases being found on the lobes of the ovary. At "B" may be seen

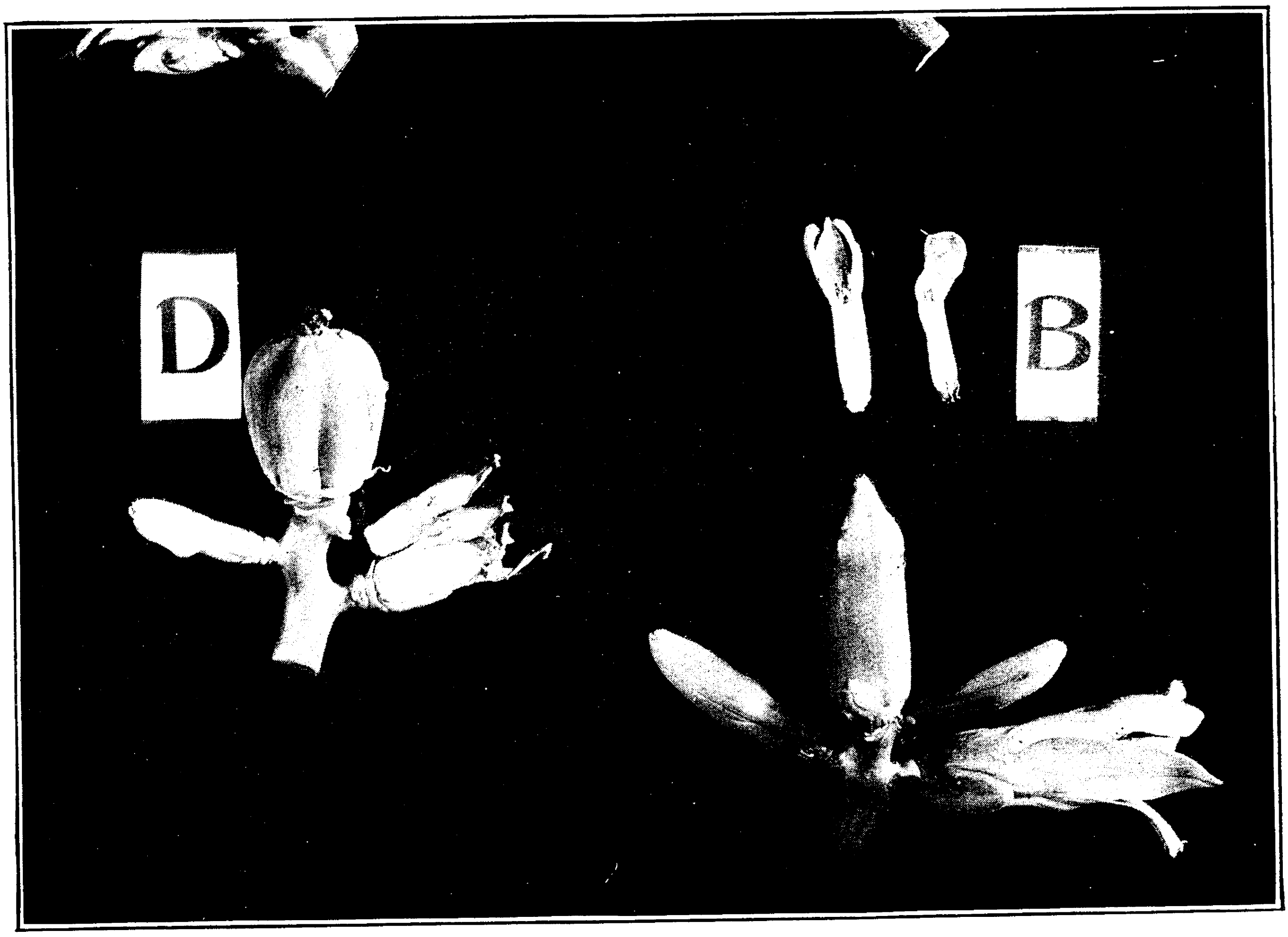


FIG. 1.—PERFECT AND MONŒCIOUS TYPES OF FLOWERS OF PAPAYA.

D. Two forms of perfect or hermaphrodite flowers in the same cluster. The lower flower to the right is of the normal form; the upper has the stamens at the base of the ovary, which is in shape like that of the diœcious type. B. Staminate flower of the monœcious type above; normal cluster below.

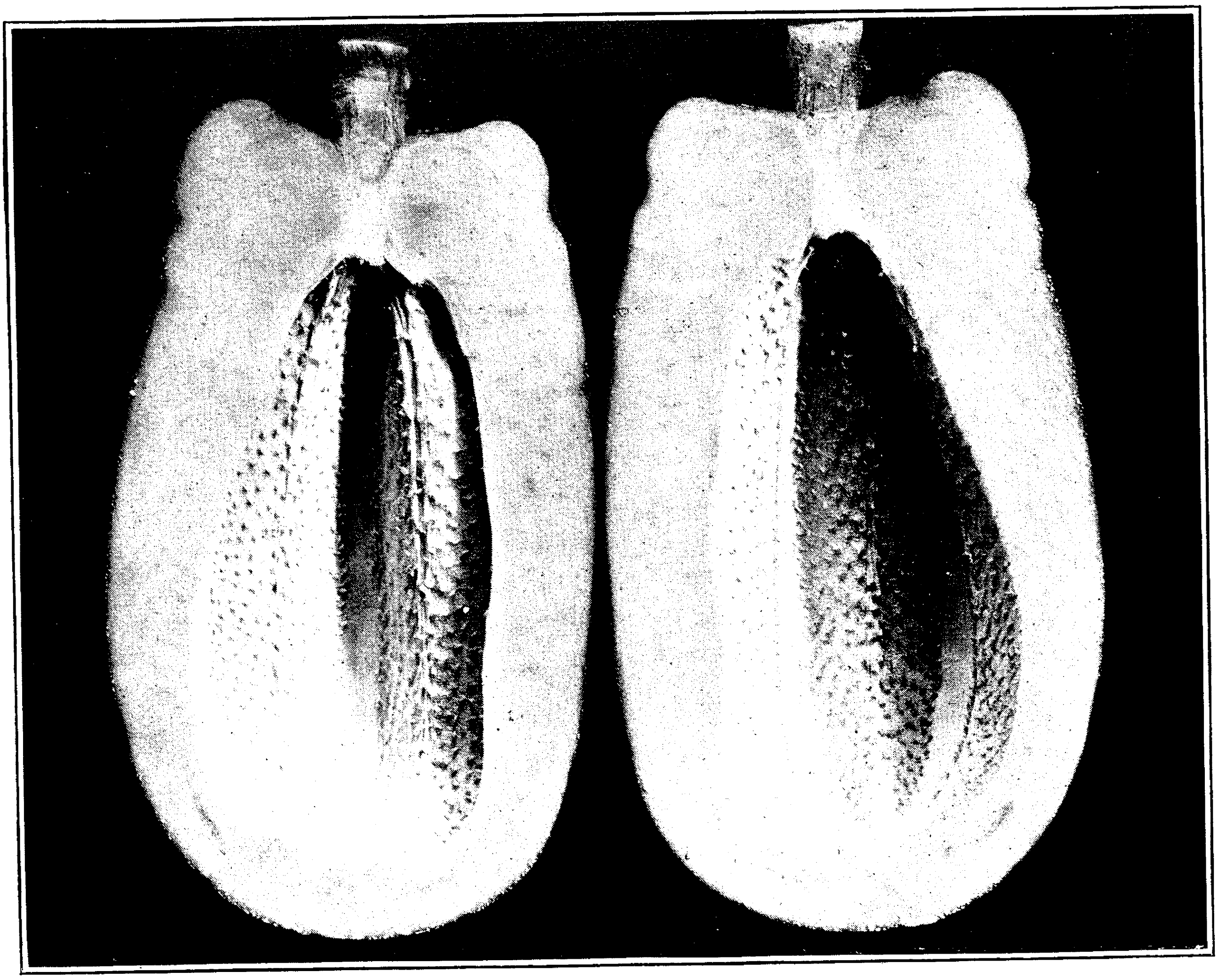


FIG. 2.—A SEEDLESS PAPAYA GROWN FROM AN UNPOLLINATED FLOWER.

the ordinary staminate flower of the monœcious type and below is a normal monœcious cluster.

It has been shown, then, that it is possible to make the cross to which reference was made in the annual report for 1910 and to get a fair proportion of monœcious trees in the offspring. The answer to the third inquiry, which has been raised, namely, to what degree the characters of the female parent will be reproduced in the monœcious offspring, must await the ripening of the fruit and then may be only suggested. The problem involved in the fourth inquiry must remain open for some time.

The same series of inquiries arose regarding the ninth combination where pollen of a staminate monœcious flower was applied to diœcious stigma, and similar questions in relation to the other possible pollinations. In the list of pollinations (p. 27) those which have proved more or less successful are indicated by the letter "S," while those unsuccessful are indicated by the letter "U." It will be seen that the ninth and all other pollinations including the use of pollen from the staminate flower of the monœcious type have failed to fertilize the ovaries. This includes with the ninth, the second, third, fifth, and thirteenth. It would not be safe to conclude from the evidence now in hand that all of these combinations are impossible, but further studies of this pollen must be made.

Setting these aside for the present, therefore, some attention may be given to the result of other pollinations. The latter have been made too recently to have shown much beyond their ability to fertilize. The first and fourth have set fruit in a fair proportion of cases and these fruits probably contain seeds. The sixth has proved successful so far in one instance only. In this one fruit has set, but what the effect has been in seed production can not yet be determined. The same is true of the twelfth. A reasonable proportion of the pollinations of the fourteenth, fifteenth, and sixteenth types have been successful.

The tenth pollination is interesting in showing the effects of breeding within the diœcious type. The progeny of one set of pollinations has been brought to fruit production. None of these plants shows any tendency toward the monœcious type. They include pure pistillate and pure staminate individuals only. This evidence, so far as it goes, is confirmatory of the theory that the monœcious and diœcious types are rather distinct and that the intermediate forms are variants.

Early in the work it was discovered that a certain papaya tree growing on the station grounds was devoid of seeds in all fruits which were examined. It was desired to learn, first, whether this seedless condition is due to lack of pollination; and, second, whether it is possible for the papaya fruit to develop without the fertilization of the ovary. To get some light on these questions a number of flowers of this tree were hand-pollinated with pollen from a staminate flower of the diœcious type. Several other flowers were sealed in paraffin sacks several days before opening to prevent pollination by natural means. All these flowers, both pollinated and unpollinated, developed into full-grown papayas.

Flowers on other trees have been sealed without pollination, but in most instances have failed to produce fruit, the pistils falling off within a week or two. On some trees, however, it has been found that sealed unpollinated flowers have produced normal papayas, except that they have been without seeds and have been smaller in size than the fruits from fertilized ovaries. (Plate III, fig. 2.)

From the above statements it seems justifiable to conclude, first, that pollination is not always necessary for the production of fruit in the papaya, and, second, that seedlessness in the case of the first tree mentioned above is probably not due to a lack of pollination, since the pollen used in the pollinations was of the type which usually gives good results and also because the flowers of this tree have the same opportunities to become fertilized as those of the surrounding trees which produce fruit containing seeds.

PRUNING.

The papaya tree has some tendency to branch. The branches soon begin to bear fruit. This usually results in the production of a large number of fruits per tree, but they are likely to be small. Experience, therefore, at this station seems to indicate that to get large-sized fruit it is best to prune off these branches when they first appear, allowing the vitality of the tree to pass along the main trunk and develop its fruits.

THINNING OF THE FRUITS.

One of the characters of some papaya trees is to set very many more fruits than there is room for on the trunk. A large number of such trees have been found among the crosses referred to (p. 27) under the eighth type of pollination. Such fruits can never develop normally in size or shape, but crowd each other and thus become distorted. In the case of such trees it has been found necessary to thin the fruits, leaving usually only one fruit to each flower cluster or in the axil of each leaf.

SHIPPING EXPERIMENTS.

Several years ago this station, in connection with other fruit-shipping investigations, made trials of placing this fruit in several markets on the Pacific coast. It was taken to San Francisco and thence as far north as Vancouver, B. C., where a fair proportion of it arrived in good condition, notwithstanding the lack of refrigeration on the rail journey, unusually warm weather, and delays in transit. It was apparent, however, that there are marked differences in the carrying qualities of papayas from different trees, some being unsuitable for shipment.

At the time referred to the station was not growing papayas in sufficient quantity for shipping tests and the supply available was such as could be found in small orchards supplying the Honolulu market. Recently the trial shipments have been resumed in a very small way by sending to San Francisco a few papayas grown at the station grounds. The purpose was to further test in general the possibilities of placing this fruit in the mainland markets and in particular to make trial of the carrying qualities of some varieties that are being grown at the station.

This work was undertaken prior to the recent quarantine regulations of the State of California, which temporarily prohibit the importation into that State of all fruits from Hawaii except bananas and pineapples. The fruit fly has not been found in the papaya, and it may be demonstrated that it does not injure this fruit. Until this matter is settled, no shipping of papayas to the mainland can be done; but the results of the work are herewith published for the significance which they have upon the papaya as a shipping fruit wherever grown or marketed.

The fruits were forwarded in refrigeration per steamship *Sierra*, sailing from Honolulu on April 19 and arriving in San Francisco on April 25. All the fruits were beginning to ripen when they were gathered from the trees, most of them exhibiting only the first indications of yellowing. They were gathered on the day preceding that of the sailing of the ship and were packed in excelsior in open crates, each fruit having been wrapped in paper.

These experiments were upon a small scale, but so far as they go their indications are the most favorable of any papaya shipments that have been made from this station. The reports received from those to whom the fruits were sent indicate that with the exception of one fruit the papayas were too green to be eaten on arrival in San Francisco, and a period of 5 to 12 days elapsed before they became sufficiently ripe in ordinary air temperatures. Considerably less time than this would be sufficient to distribute the fruit through the various channels to the consumer and would also offer the opportunity for a permanent supply with steamers sailing not more frequently than at present. Peaches, cherries, and other fruit that would not stand so long a period are shipped by carload lots across the American continent.

The indications are that, as the papaya industry develops, in Hawaii or elsewhere, there will prove to be at least three important factors in the successful placing of these fruits in distant markets. One of these is on the side of production. It will be necessary to grow varieties that have good carrying qualities. Papayas differ greatly in this respect, and one of the problems upon which the station is now working is to select, segregate, and if possible improve varieties that possess these qualities in a high degree. The experiments indicate that some degree of success has already been attained. In order to make the work successful in the largest way, it will be necessary not merely to select trees of the desired qualities but to establish varieties so that they can be depended upon to reproduce their characters.

The second factor in successfully shipping papayas to the mainland is on the side of packing. The fruits must be gathered at the right time and must be carefully handled and packed, wrapping each fruit in paper and surrounding it with sufficient packing material to prevent bruising and yet not interfere with refrigeration. The crate should be open so as to permit the rapid cooling of the fruit, which should be put into refrigeration as soon as possible after picking.

The third factor pertains to the proper distributing of the fruits. Papayas are unknown on the mainland except to the few who have visited Hawaii or some other tropical land. If placed in the usual wholesale market, the fruit would probably rot before a buyer would appear who knows the papaya. Therefore some other means of finding the consumer and of developing the taste among those unfamiliar with the fruit must be devised. In some markets there are dealers who make a specialty of handling rare and unusual fruits, and they have their special class of customers. Where such dealers are not to be found it would seem best to begin with large hotels and fashionable clubs and restaurants. With these special arrangements could be made to receive small shipments regularly and thus build up a market.

MISCELLANEOUS WORK WITH PAPAYAS.

Other miscellaneous work with the papayas during the year has included the combating of insects, including cutworms, the small larva of the genus Amorbia, which hides among the flowers and emphasizes the need of thinning them, and black and green aphids on fruits; and the collecting and drying of the milky juice of the fruit which has been carried on only in a preliminary fashion.

INVESTIGATION OF BANANAS IN HILO AND OLAA, HAWAII.

Early in December a letter was received from Hon. L. A. Thurston, general manager of the Hilo Railroad, reporting certain difficulties with the Bluefields banana in Hawaii. It was stated that this variety of banana was failing of success because of the breaking off of the pseudostems and the falling of bunches. It was also stated that the same difficulty was found with another banana which had been introduced into Hilo from the district of Hamakua, probably 12 or 15 years ago, and is reported to have been brought to Hamakua by the captain of a ship which anchored off this coast. This latter variety has been regarded by some observers as being identical with the Bluefields.

In view of the recent revival of interest in the banana industry it was deemed important to investigate this matter. The horticulturist proceeded to Hilo on December 13, returning December 17.

It was found that a very large percentage of the Bluefields plants in some localities broke or bent over; in other places this was not so common. There appeared to be several causes at work contributing to this trouble. It does not appear to be due to any inherent weakness of the variety; nor, we believe, to any lack of adaptability to Hawaiian conditions. Some of the causes at work appear to be as follows:

(1) Close planting. The practice in vogue in the planting of the Chinese and other small growing varieties had been adopted for the Bluefields. It was found that they are being planted as close as 6 by 6 feet in some cases, and the widest planting found was about 10 by 10 feet. This variety has been found to do best at 12 by 15 or as wide as 15 by 15. The close planting makes too dense a foliage and the plants become thin stemmed and spindling, as is the case with most plants that are crowded and reaching upward in the effort to get light.

(2) The bunches are left upon the plant until they become extremely large and heavy. On one plantation the writer was informed that from 90 to 100 pounds was the average weight of the bunch when cut. On another plantation the information was given that one bunch had weighed as high as 140 pounds. It is the custom in Hawaii to leave the bunches on the plants until they are almost ripe. In this way they acquire their full flavor, but in commercial growing for export such bunches would decay before reaching the market. This variety of banana, as grown in the West Indies and Central America, is cut some time before it has attained its full weight.

(3) Lack of pruning. It was found that the pruning off of the dead leaves has not been practiced. These are allowed to fall back against the pseudostem. This adds to the darkness in which the pseudostem is confined and it also retains moisture. It appears also that this may be a contributing cause of the failure of the plant to sustain its load of fruit.

SEARCH FOR BANANA DISEASE.

A search was made for plants which might show indications of the banana blight, now prevalent in the West Indies and Central America. which is believed to be due to a Fusarium. No certain evidence of this disease was found. In one field the plants were reported to have died back in a manner somewhat similar to that of bananas affected with Fusarium. These plants, however, were growing in grass and had not the opportunity to flourish. Some of the plants showed discolorations in the pseudostem which looked somewhat suspicious. Material was collected from a number of plants which showed more indications of the disease than any others, and this material has been forwarded to the Department of Agriculture in Washington to be submitted to specialists in this disease. The final report upon this material has not yet been received.

THE SO-CALLED HAMAKUA BANANA.

This banana, as has been stated, was brought to Hilo from Hamakua. The writer saw it growing in Hilo in 1904 and it was, at that time, reported to have been there some years. It has been regarded by some as identical with Bluefields, and in some cases no attempt has been made to distinguish between the two in planting. A search was made for bananas having fruits which might be known to have come directly from the Hamakua stock. Some were found which the writer was assured had grown from this stock. A careful comparison was made between these and the Bluefields. The Chinese variety was also brought into the comparison of flavor and texture. The fruits of the Hamakua lack the characteristic aroma of the Bluefields and resemble closely in flavor the Chinese variety. In form and coloring they are much like the Bluefields. The specimens in hand were larger than any Bluefields that could be found. yet this difference would not be sufficient in itself to show that the two are not identical. The conclusion was reached that the so-called Hamakua banana, while distinct from the Bluefields, resembles it so closely that the two could probably be marketed as the same variety.

The opportunity was not afforded to compare the two in relation to other characters. One of the strong features of the Bluefields banana, as grown in Central America, is its shipping quality. This is very essential in any commercial banana. Whether the Hamakua would prove a good shipper, or not, can not be stated, and for this reason, if for no other, intending planters should confine their commercial plantings to the Bluefields and the Chinese varieties, which are known to stand transportation.

THE GRAPE.

There is a small grape industry in Hawaii. Grapes are grown for home use in almost all parts of the islands at the lower elevations. In and about Honolulu and Hilo they are grown to supply the local market for fresh grapes, while in Makawao on Maui, and also in Hilo and Kona on the island of Hawaii, there is a small wine industry.

The last session of the Territorial legislature requested the station to prepare a small press bulletin on the growing of the grape in Hawaii for publication in the Portuguese language, since the industry is almost entirely in the hands of the Portuguese. Some investigation was made of the methods in vogue and the difficulties which have been met with by those engaged in the business, and a small pamphlet on the subject was issued.

THE MANGO.

NEW VARIETIES.

The work with the mango has continued along much the same lines as formerly, and, with the exception of spraying experiments, little new work has been undertaken. The working of new varieties into the orchard by budding and grafting has been continued. Some of the new varieties have been coming into bearing during the year. One of the most striking of these is the Brindabani. Perhaps the most distinctive features of this variety are its peculiar form, its heavy bearing habits, and its coming into bearing at a remarkably early age. It came into the bearing of mature fruit within 18 months from the date of grafting. The tree at 2½ years old from scion and bearing its second crop of fruit is shown in Plate IV. The fruit had been severely thinned to prevent the breaking of the tree.

MANGIFERA INDICA. Indian variety Brindabani.

History.—The original stock was received in May, 1908, from the Bureau of Plant Industry of the Department of Agriculture as an inarched pot plant. This plant was inarched upon a seedling mango tree in the orchard on December 12, 1908, produced its first crop in the summer of 1910 and its second main crop in 1911.

Description.—Form roundish oblate; size medium, averaging 8 to 9 ounces; cavity shallow, flaring, irregular; stem slender, persisting well; apex depressed; surface smooth and undulating; color green, blushed with orange and red, being a rich orange yellow when exposed to the sun and mature; dots yellow, small, very numerous, and slightly raised; bloom bluish white, quite abundant; skin moderately thick, tough, tenacious; flesh moderately thick, orange yellow, coarse, juicy, with an abundance of fiber; seed reniform and rather thin; flavor sprightly, a trifle acid, and quite pleasant: quality fair to good. Season July to September for the main crop at Honolulu, Hawaii.

The tree is small of stature and has a broad spreading habit, lower branches often sweeping the ground. (Hunn.)

THE OAHU.

History.—A seedling tree about 6 or 7 years of age bore fruit this year, and its characteristics have given justification for naming it Oahu. It is probably a cross between the Hawaiian sweet mango and the Crescent. Although the husk is present, the seed presents an undeveloped condition with often just the seed coat present. About 75 per cent of this year's crop has had no viable seed. (Pl. V.)

The Oahu is valuable as a large, fine-appearing fruit of good quality. Its nearly seedless condition makes a thin husk with a large proportion of flesh. No mango weevil, *Cryptorhynchus mangiferæ*, has been found within these mangoes, and it will be interesting to note what may be the result of the attack of this insect on a fruit which contains no seed upon which its larva may feed. The Oahu is also worthy of propagation as a basis for breeding toward complete seedlessness.

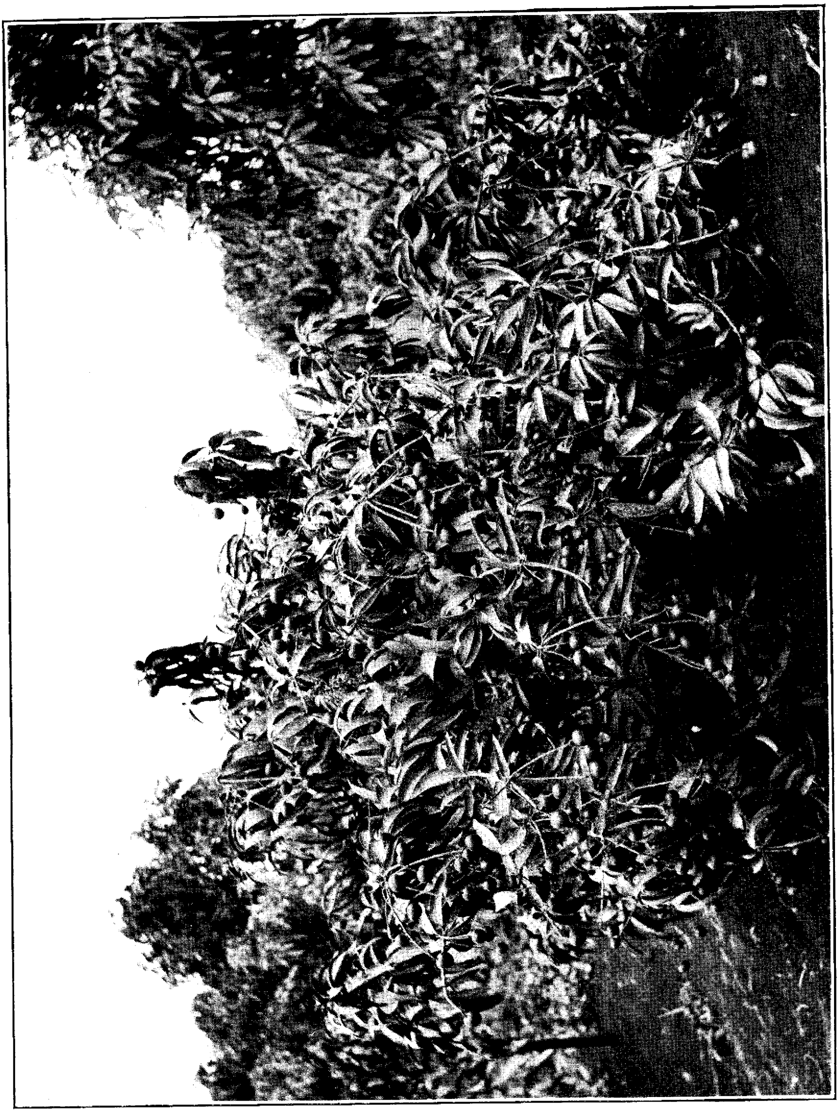
Description.—Form oblong, heavily shouldered at the cavity end and tapering toward the apical end; size large, averaging in weight from 10 to 15 ounces; cavity shallow, flaring, irregular; stem slender; apex variable, ranging from a point to a depression; surface moderately smooth and undulating; color pale yellow with a reddish blush on the exposed side: dots numerous, small, yellow, depressed; bloom bluish white, moderately abundant; skin moderately thick, tough, very tenacious: flesh thick, bright yellow, juicy, with an abundance of fiber; seed dried up or represented by just the seed coat; flavor rich, moderately sweet; quality good. Season June to August at Honolulu, Hawaii.

This tree is of the average height and presents a broad spreading habit. (Hunn.)

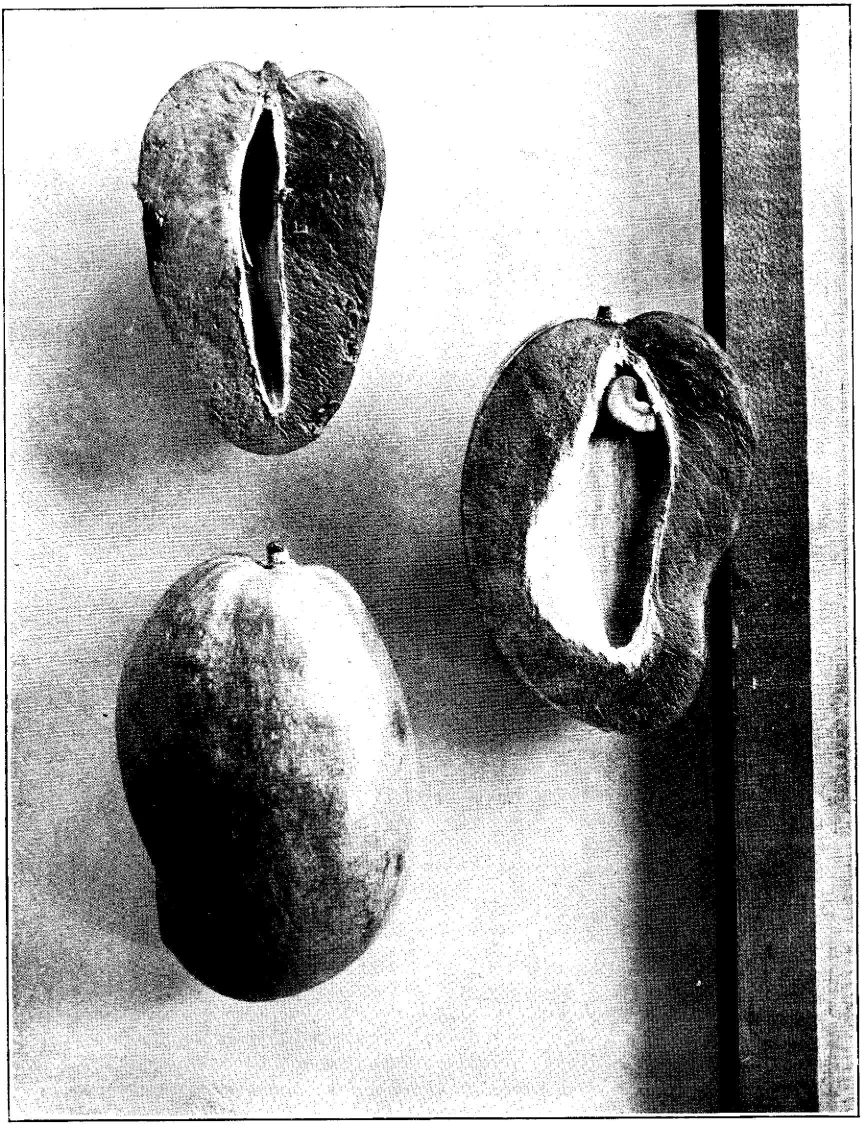
SPRAYING.

The mango in Hawaii is quite seriously attacked by a fungus disease sometimes called mango blight and which is due to the fungus *Glœosporium mangiferæ*. This disease causes the destruction of the flowers, the young foliage, and sometimes the young twigs. It also results in the spotting and rotting of the fruits of susceptible varieties. The same leaf-folding larva to which reference was made when

PLATE IV.



THE BRINDABANI MANGO BEARING ITS SECOND MAIN CROP OF FRUIT 2½ YEARS AFTER GRAFTING.



THE OAHU, A NEARLY SEEDLESS MANGO.

discussing the avocado also attacks the mango, its chief damage being done to the flowers and young fruits. Spraying experiments along the same lines as indicated in the case of the avocado have been carried on. It has not been found difficult in years past to control the disease with Bordeaux mixture, but because of red spider and thrips which sometimes infest the mango it was thought well to make some tests of the sulphur sprays also. The results of these spraying experiments, as well as the methods upon which they have been carried on, are given in detail, so far as they are at present available, in Bulletin No. 25 of this station, on the Avocado in Hawaii.

FRUIT MODELING.

Fruit modeling as a means of record has been used to some degree in the study of mango varieties. Modeling has some advantages over photographing or verbal description as a permanent record. The method used was applied at the station first by the late Mr. F. N. Otremba, who was an expert in this line of work. The method, however, is so simple and convenient that it does not require artistic talent to use it successfully. Other members of the staff have found it convenient, and it might be worth while here to record the method for the convenience of others who may wish to apply it.

The principle involved is simply to make a mold by pouring a medium of glue and gelatin about the fruit to be modeled. This when cold is cut open and the fruit removed, leaving the mold, into which plaster of Paris is placed in a liquid form and allowed to solidify, making the cast. The details are as follows:

The mold.—This is formed of fish glue and gelatin. The glue should be reduced to the liquid form with water by being heated in a kettle surrounded by water and placed over a slow fire. When liquefied add the gelatin. About 1 pound of gelatin to 2½ pounds of glue has been satisfactory.

The box or container.—This may be made of wood, but we have found that for fruits of ordinary size a flower pot can be used very conveniently and saves much trouble. If made of wood, the box must be held together by wire or twine so that it can readily be taken to pieces. A flower pot has the advantage of being larger at the top than at the bottom and therefore the mold can be removed without great difficulty. The inside of this container must be well coated with shellac and each time before the mold is made must be well oiled. A mixture of 50 per cent olive oil and 50 per cent kerosene is, perhaps, most satisfactory, but cottonseed or ordinary raw linseed oil would probably serve the purpose.

Making the mold.—Oil the fruit to be modeled and place it in the container, which should be large enough to allow an inch or more on each side of the fruit and between the fruit and the bottom. The fruit may usually be suspended from a small nail driven through a stick which rests upon the top of the pot and is tied down at the ends to the shoulder of the pot. This will prevent the fruit from rising to the surface when the glue is poured into the container. While the glue is warm, but not too hot, pour it into the container, distributing it on all sides so as not to crowd the fruit to one side. Allow it to remain so overnight. In the morning remove the mass of glue from the container. With an oily knife cut one side of the mass from end to end or as far as may be necessary. Gently release the fruit and remove it, leaving the mold empty. At the same time cut a small opening at the highest point to receive the plaster of Paris. Allow the mold to dry for half an hour and then apply to its interior, with a brush, a coating of about 10 per cent formalin to harden the surface.

Making the cast.—After the formalin has evaporated apply a coating of oil to the interior of the mold and also oil the interior of the container into which the mold must now be placed. It is sometimes necessary to tie the mold together before replacing it in the container. Take the required amount of plaster of Paris and add to it enough water to make a thick liquid. Mix this well so as to free it from all lumps and pour it into the mold through the opening made in the top. Shake the mold with a circular motion to force the plaster of Paris into all parts. Allow it to stand for an hour or more when it will be sufficiently solidified to be removed. It may then be taken out with the same care with which the fruit was removed.

Coloring the cast.—If it is desired to have a reproduction of the color of the fruit as well as the form, this may be done with water colors, but for this part of the work some familiarity with color work will be necessary. Any slight imperfections must first be removed. Sometimes minute holes, which have failed to be filled by the plaster of Paris, are to be found. These may be filled by first dipping the cast in water and then painting it with a very dilute coat of plaster of Paris. These may not be filled by one or two coatings, but care must be taken not to alter the shape of the fruit. To prevent the colors from striking into the cast it is necessary to coat the latter with a very thin glue, applied with a brush, after which the colors may be applied.

CITRUS FRUITS.

The citrus orchards have been extended somewhat during the year. A number of new varieties have been budded into the orchards and nurseries. There are now growing on the station grounds the following varieties of citrus trees, of which quite a number budded in 1909 are in fruit at this writing:

ORANGES. (29 varieties, 126 trees.)

Bouquet des Fleurs.
Centennial.
Dancy Tangerine.
Dugat.
Du Roi.
Enterprise Seedless.
Golden Buckeye Navel.
Golden Nugget Navel.
Hart Tardiff.
Jaffa.
Joppa.
King Mandarine.
Lamb's Summer.
Magnum Bonum.
Majorca.
Maltese Blood.
Mediterranean Sweet.
Paper Rind St. Michael.
Parson Brown.
Pineapple.
Ruby Blood.
Satsuma.
Scented Orange.
Tangerine.
Thompson Improved Navel.
Valencia Late.
Variegated Navel.
Washington Navel.
Navelencia.

POMELO. (11 varieties, 59 trees.)

Duncan.
Imperial.
Whitney Imperial.
Marsh Seedless from California.
Marsh Seedless from Florida.
McCarty.
Pernambuco.
Royal.
Tresca.
Triumph.
Woodworth.

LEMON. (6 varieties, 35 trees.)

Seedless Campucinni.
Eureka.
Genoa.
Lisbon.
Ponderosa.
Villafranca.

LIME. (2 varieties, 6 trees.)

Kusaie.
Tahiti.

CITRON. (1 variety, 1 tree.)

Citron of commerce.

ACCESSIONS AND DISTRIBUTIONS.

ACCESSIONS.

Among the numerous accessions of the year a few should receive special mention. Seeds of the date palm (*Phœnix dactylifera*), said to be of unusual merit, were collected by Dr. Wilcox in Arizona during the early part of the year. These are reputed to be of a strain which produces good fruits from seed. They have germinated well and will be soon ready for planting out.

The *Agava lespinassei* and *A. zapupe* were received from the Office of Foreign Seed and Plant Introduction, Department of Agriculture. Most of these were given into the custody of Mr. William Weinrich, manager of the Hawaiian Fiber Co.'s plantation on this island, where they will be propagated and from which source the station can secure plants for distribution if desired later. A few of the plants were retained on the station grounds.

A new variety of pigeon pea known as Cadios was received from the Philippine Islands.

Plants of *Canarium commune*, S. P. I. No. 25684, were received by mail and are recovering from the effects of this long transportation.

Greigia sphacelata, a decorative bromeliad related to the pineapple, was received from the same source as the above. The fruit of this species is said to be held in high esteem in Chile.

Several species of Anona have been received and planted.

Bud wood of a number of varieties of citrus was received from Mr. G. P. Wilder, who collected them on his tour around the world. These included a seedless lemon called the Capucinni, and bud wood was received from Kauai of a variety of orange known as the Scented Orange, which was observed by the horticulturist several years ago, and which had the finest color of any orange that he has seen growing in Hawaii.

DISTRIBUTIONS.

Quite a large number of plants have been propagated and distributed during the year. The chief purpose of this has been to introduce certain varieties of plants and disseminate them more widely in the Territory. Among these have been the Merced variety of sweet potato. This is probably the same variety as is known in the East under the name "Jersey Sweet." Reference was made in the last annual report to the possibilities for marketing this variety of sweet potato on the mainland. In order to assist in this matter, plants or roots have been distributed to all who have applied. Something over 3,000 plants have been sent out besides a number of shipments of roots.

Banana offsets have been distributed in considerable numbers. The supply of the Bluefields variety, for which there is a great demand, has become so reduced that the distribution of these has been suspended for the present. It is hoped that these will soon be sufficiently disseminated in the islands so that the station will no longer need to engage in the distribution.

About 300 seeds of *Aleurites cordata*, one of the wood oil nuts, were received from the Office of Foreign Seed and Plant Introduction, Department of Agriculture, and were distributed to several parts of the islands, where it is thought they will have the best chance to prosper. The same species has been planted at several times on the station grounds, but this locality does not seem to be well adapted to the plant.

The orchards and nurseries of the station have now grown sufficiently so that it has been possible during the past year to distribute citrus bud wood to all who have applied. This material has been of several varieties.

In connection with the papaya work reported above, about 250 packages of best selected seeds have been distributed and about 9 pounds of ordinary selected stock.

The *Carissa arduina*, a new fruit and ornamental shrub described in the report for 1910, has been distributed to the extent of over 2,000 plants and many packages of seeds.

The roselle has been sent out in about 80 packages. This plant is now rather widely disseminated and it does not seem necessary for the station to longer engage in its distribution.

Numerous requests have been received for seeds of pigeon pea and cowpea for windbreaks and cover-crop purposes, and over 200 pounds have been distributed.

HIBISCUS.

Mr. Valentine S. Holt, assistant in horticulture, donated to the station his private collection of hibiscus. A small amount of time has been devoted to the breeding of new varieties of this most ornamental plant. There are probably few, if any, plants of more promise for ornamentation in the islands than the hibiscus. The plant grows in comparatively dry and poor soil and has been planted at the station in places formerly occupied by weeds and lantana and where little else would prosper. While there may be some who will think that the hibiscus is of little economic importance it may be said that its popularity is evinced by the large demand for varieties of this genus. The first Hawaiian exhibition of hibiscus was held during the month of June, 1911, and astonished even those most familiar with these plants by the number and beauty of the varieties which were brought together. The station cooperated in this undertaking by exhibiting its flowers. Over 3,000 cuttings of different varieties have been sent out. A method has been adopted in this propagation work by which the plants can be multiplied rapidly at nominal expense. Cutting beds of ordinary beach sand have been prepared in the open. The cuttings are tied up in bunches of 50 to 100 and planted in the sand where they root readily. They are thus rapidly put in and can be rapidly removed.

NEEDS.

The chief needs of the department of horticulture at the present time are increased facilities for propagation. On this subject, Mr. Hunn, who is in charge of the propagation work, submits the following data:

> During the year I presented you a lengthy report of the condition of affairs in regard to our present situation and facilities for seed and plant propagation. A resubmission of this report with added emphasis would be in place at this time. Our facilities are inadequate to successful propagation. There is no usable means by which to obtain bottom heat so needful in propagation work. The temperature can not be regulated. Protection is almost nullified by our present appointments, while diseases, insects, and rodents must be constantly combated. The condition in the potting room remains the same, while the shade houses are deteriorating. We have had to brace some of the walls of the shade houses and have removed benches which were rotten and of no further use.
>
> The situation has been partly relieved by the erection of six outside benches—each 18 feet long and 4 feet wide. The supports were erected in pots which are kept constantly filled with water, thus making the benches ant proof. A woven-wire box, 8 meshes to the square inch, 2½ feet high, has been built on each bench. These benches were primarily erected for the purpose of hardening off plants and to protect them against ants and rodents. Circumstances have compelled us to use them for propagation benches.

The need for better facilities for propagation has certainly become imperative. There is no glass house in the horticultural department and no means by which delicate plants can be protected from heavy rains. The shade houses, which have been very satisfactory for older and more established plants, are now in a dilapidated condition and are liable to fall down in any storm. It is hoped that some arrangement may be made for this work.

In closing it is desired to express appreciation of the very faithful services of Mr. C. J. Hunn, assistant horticulturist, and Mr. Valentine S. Holt, assistant in horticulture.

REPORT OF THE CHEMIST.

By W. P. Kelley.

The work of the chemical department during the year has been devoted to soil investigations, plant physiology, and miscellaneous analyses.

SOIL INVESTIGATIONS.

The soil investigations have been continued along the lines suggested in the previous report. The conditions in certain cultivated sections of the islands, together with the experience of farmers and members of the station staff, have convinced us of the need for an investigation of soil factors not commonly studied in agricultural investigations. The difficulties attending the continued cultivation of pineapples on Oahu and the failure to manage successfully some of these soils by the use of the usual cultural methods and fertilizers indicate that other factors demand attention. These investigations have been along two general lines, which may be classified as physical and chemical. The study of soil physics has been conducted with special reference to the movement of water in certain types.

For a considerable time it has been apparent that one of the fundamental difficulties in pineapple cultivation is faulty drainage, and it already appears that if a permanent system is to be evolved under the prevailing climatic conditions, it is necessary more thoroughly to comprehend the physical factors involved. The results thus far obtained have a direct application to the pineapple soils of Oahu. In addition it is believed that these soils offer opportunities for studies of a scientific nature, the result of which may have a much broader application. In certain of these soils physical factors play an abnormal part in their productivity, but it is also likely that in such instances there is only an exaggeration of what exists in soils throughout the islands and to some degree everywhere.

THE MANAGEMENT OF SOILS.

It is commonly held that the free circulation of soil moisture is indispensable to the normal growth of higher plants. All plants, however, are not equally sensitive to adverse physical conditions. The pineapple is a particularly sensitive plant and often fails to vegetate as a result of a number of causes. Among the easily recognizable causes of failure, the lack of sufficient drainage is one of the most apparent. Usually cultivation and frequent tillage accelerates drainage by keeping the soil open and preventing its becoming compacted. At the same time a loose soil is more retentive of moisture in times of continued dry weather.

The frequent and thorough tillage of certain pineapple lands in the Wahiawa district is sometimes attended by a retardation of the movement of soil water during times of wet weather. The chief cause of this condition has been found to be associated with the fact that sufficient care has not been exercised in the cultivation of these soils. At various times during the year continued rains bring about saturation of the soil, at which times the growth of weeds is very rapid. The farmers feel compelled to cultivate at such times before the soil becomes properly dried out. This cultivation has resulted in puddling the soil to such an extent that natural drainage is greatly hindered.

Particular emphasis has been placed on this phase of the question in a previous publication devoted to the management of pineapple soils.[1] In addition the investigation has led to a further study of the movement of water in other soils in the islands.

CAPILLARY RISE OF MOISTURE.

If we are to understand the peculiarities of these soils and foresee what will be the results of a given treatment, it is essential to understand the fundamental movement of water in them. Ordinarily soils contain four kinds of water, namely, water of chemical combination, such as enters into the composition of clays and other hydratable substance; hygroscopic water; capillary water; and free circulating water. The first two of these will not be discussed at this time further than to point out that the chemically combined water in pineapple soils appears to be abnormally high, the explanation of which, however, is found in the physical composition. Frequently these soils contain from 30 to 50 per cent of finely divided substances, ordinarily called clay, a large part of which contains water of hydration.

Capillary water or moisture except in times of wet weather forms the nutrient solution in which the several mineral substances necessary to plant growth are dissolved. Such water comprises thin films which more or less completely envelop the soil particles, connecting them, and the movement of which is dependent upon various conditions. The force which brings about movement in this moisture is usually referred to as capillary attraction and is caused by surface tension. The capillary movement of soil moisture in other countries has been investigated to some extent. The soils throughout Hawaii, however, are unlike ordinary soils in a number of particulars. Their chemical composition is different and the physical make-up unlike that of most soils. It is therefore of some scientific interest to determine the relative movements of water in these soils. In addition, such a study is of practical importance to the pineapple growers.

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[1] Hawaii Sta. Press Bul. 29.

In this investigation soils of widely different physical structure have been used. The following table shows the relative percentages of the different-sized particles contained in the samples used:

Mechanical composition of soils.[1]

Serial number.	Loss on ignition.	Fine gravel.	Coarse sand.	Fine sand.	Silt.	Fine silt.	Clay.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
7	13.14	....	0.77	3.64	8.85	34.54	36.28
9	16.77	0.87	8.20	22.44	13.94	23.13	13.11
15	16.66	2.54	6.28	21.17	14.57	21.90	15.50
61	25.16	.12	7.20	40.90	9.85	15.01	2.93

[1] Analyses made by the method of Hall. The Soil. London, 1908, 2. ed., p. 51.

Finely pulverized air-dried soil was prepared by rubbing samples in a mortar with a rubber pestle so as to reduce the larger aggregates without crushing the ultimate particles. Portions were then inserted into glass tubes 4 feet in length and 1 inch in internal diameter by the use of a long roll of paper, by means of which the soil was introduced into the tubes in such a way as to leave it in an unbroken column. In order to prevent the soil from falling out the lower end of the tube was closed by a piece of fine muslin stretched over it. These columns were suspended in such way as to allow the lower end to dip beneath the surface of distilled water. The upward capillary rise of moisture could be easily observed by the wetting of the soil and was measured from time to time. The following table shows the results:

The capillary rise of moisture in soils.

Time.	Heavy clay No. 7.	Silty soil No. 9.	Silty soil No. 15.	Highly organic sandy soil No. 61.
	Centimeters.	*Centimeters.*	*Centimeters.*	*Centimeters.*
10 minutes...	5.5	7.5	6.5	7
20 minutes...	7	9.5	9.5	9.5
30 minutes...	8	11	12	11.5
45 minutes...	9	12	14	13.5
1 hour.......	10	13.5	15.5	15.5
2 hours.......	11.5	16.5	20	20
3 hours.......	13	19.5	22.5	24
4 hours.......	14	21.5	24	27
5 hours.......	15	23.5	26.5	29.5
6 hours.......	16	24.5	28	31.5
1 day........	22	37.5	41	48
2 days........	24	41	45	57
3 days........	24.5	43.5	52	63.5
4 days........	25	44.5	55	66.5
5 days........	26	45	57	69.5
6 days........	27	45	58	74.5
7 days........	27.5	48	60	77.5
8 days........	27.5	48	62	79.5

These data show that the upward capillary movement of water in these soils varies between wide extremes. It was found to be greatest in sample No. 61, which is a highly organic soil from the Kula district of Maui and contains a very small percentage of clay. Next in the upward movement are soils Nos. 15 and 9, both of which are composed largely of silts and fine sand. The most retarded capillarity

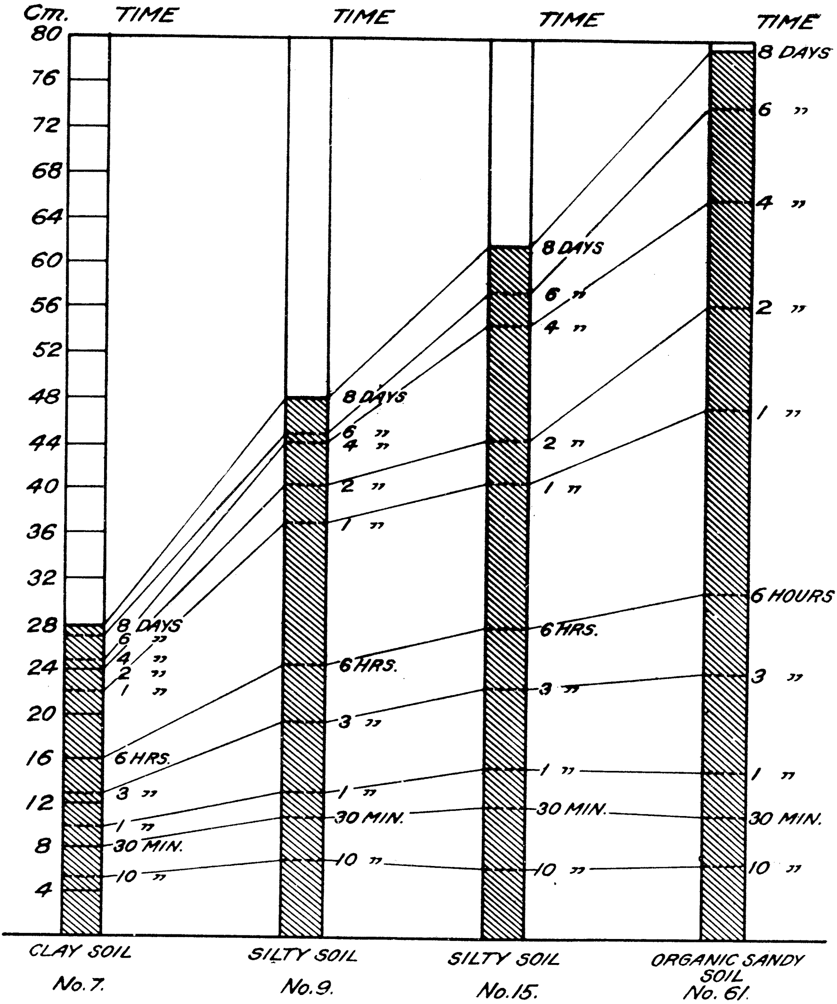

FIG. 5.—Capillarity in different soils.

was found in soil No. 7, a heavy clay. The capillarity in the different soils is diagrammatically shown in figure 5.

From this investigation it is shown that the capillarity, and hence the power to maintain a good moisture content during continued dry weather, varies in these soils between wide extremes. Clay should have a greater capillarity than coarser particles, and therefore water ought to rise to a higher level in clay soils if other factors were not involved. Loughridge [1] has shown, however, that the rate of capillarity is proportional to the size of the particles, while the maximum height to which water will rise is greater in the silts. Clays when moist gradually become colloidal, and in consequence offer resistance to the passage of water by increasing the friction, which finally becomes sufficiently great to balance the force of capillarity. The amount of colloidal clay in soils is not always proportional to the percentage of clay found by mechanical analysis and, further, clays of different sorts become colloidal in varying degrees.

It should not be considered that the conditions in these experiments exactly duplicate those of the field, and consequently the movement of water herein reported is not the same as takes place in the field. On the other hand, however, the data are comparable and give an idea of the relative movements that take place under natural conditions. The general field observations are in accord with the experimental findings.

In addition to the upward capillary movement of soil moisture there is also what is known as downward capillarity. With a view of determining the rate at which this movement will take place, an additional set of tubes prepared as above were kept under a constant water head of 1 inch. The following table records the results:

Downward capillarity in soils.

Time.	Heavy clay No. 7.	Silty soil No. 15.	Organic sandy soil No. 61.
	Centimeters.	*Centimeters.*	*Centimeters.*
5 minutes	8	10	9
15 minutes	15	16	14
25 minutes	19	20	19
45 minutes	25	26	25
1 hour	29	29	32
2 hours	44	45	45
3 hours	61	60	60
4 hours	74	76	69
5 hours	80	80	76

The downward capillarity of these soils is thus shown to be essentially the same. In addition the movement under the conditions of the experiment was very much greater than was the capillary rise. These data, however, should not be interpreted to mean that the downward flow of soil water is the same in these soils. The rate at which water will flow through the soil in addition to the capillary movement of moisture forms a more adequate basis for conclusions regarding drainage. In order to determine the percolating power of these soils the same tubes used in the last set of experiments were allowed to stand until the downward movement of moisture had reached the bottom of the tubes, after which the amount of water which drained through was collected in graduated cylinders and measured.

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[1] California Sta. Rpt. 1904, p. 33.

Percolation through soils.

Time.	Heavy clay No. 7.	Silty soil No. 15.	Highly organic sandy No. 61.
	Cc.	*Cc.*	*Cc.*
1 hour	10	22	15
2 hours	11	40	30
3 hours	12	57	45
4 hours	14	70	58
5 hours	16	80	72
1 day	66	155	184
2 days	93	222	407
4 days	136	363	817
5 days	155	435	1,095
6 days	170	508	1,215
7 days	182	586	1,345
8 days	190	662	1,490
9 days	196	741	
10 days	210		
11 days	218		
12 days	226		
13 days	235		

These data indicate the relative rates of drainage that would be expected to take place in the field. As already stated, soil No. 7 is a heavy clay, having been taken from a field in which natural drainage is very poor. By comparing the mechanical composition and the percolation, it is seen that the soils containing the highest percentage of clay and fine silt permit the flow of water through them at the slowest rate. The air spaces in soils of high clay content are small in size, so that the capillary force, being proportional to the surface, is also great; but the resistance offered to the movement of water is, on account of friction, relatively greater in clay soils. The clay in soil No. 7 is not composed of silicate of aluminum alone but contains a very high percentage of iron, the analyses of which have shown as high as 35 per cent Fe_2O_3. A part of this iron exists as ferric hydrate, which, in addition to containing water of hydration, becomes gelatinous when wet, thus further inhibiting the free movement of water through it. Also we have evidences of the existence of a double silicate of iron and aluminum, which compound is colloidal and very finely divided and appears to have a tendency to reduce the flow of water through the soil even more than ordinary clay.

The accompanying diagram (fig. 6) shows the rate of percolation through different soils.

The samples used in the previous experiments were thoroughly air dried at the outset and it was observed that the percolation was greater at the beginning than toward the end of the experiment. This may be taken as evidence of the gradual hydration of colloids, which by somewhat swelling tend to hinder the free passage of water.

From the data it appears that drainage would gradually become slower during a long-continued wet season, especially in soils similar to No. 7. In the more porous soils, however, such effects would not be observed. The subsoil underlying No. 7 also contains a very high percentage of clay, which makes natural drainage more difficult. In addition the organic matter of this soil is low.

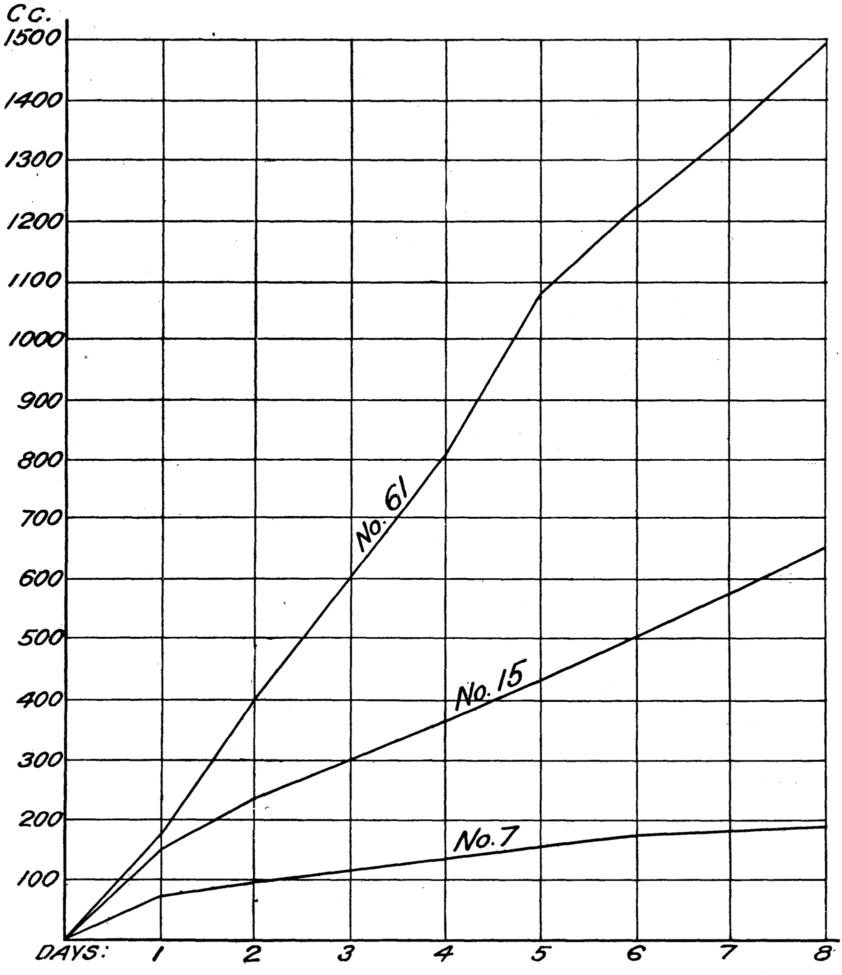

FIG. 6.—Percolation through different soils.

The management of soils similar to No. 7 requires the greatest of care if good tilth be maintained. Under no circumstances should they be tilled when wet and, in addition, crops should be rotated and organic manures and green manuring crops used as often as possible. By increasing the organic matter of such soils, a granulation of the clay can be gradually effected and at the same time greater porosity and better natural drainage will result.

SOIL ORGANIC MATTER.

An extensive study of the several methods previously used in the determination of the so-called humus in soils has been made by Mr. W. T. McGeorge, assistant chemist, and the results of this investigation are now being prepared for publication. In this paper it will be shown that none of the methods usually employed in this determination can be relied on with Hawaiian soils. A modification of the Cameron-Brazeale method, however, has been found to be both accurate and practical. Hawaiian soils contain abnormally large percentages of an extremely finely divided ferruginous clay which will remain in suspension in an ammoniacal extract indefinitely and can not readily be removed by ordinary filtration, sedimentation, or coagulation. The use of a clay filter, modified so as to prevent the absorption of organic matter and at the same time overcome any dialyzing effect, has been found to be effective and practical. In this connection some attention has been given to a study of the organic matter of Hawaiian soils, and sufficient data have already been obtained to warrant the conclusion that the organic matter of these soils is made up of extremely complex mixtures, varying from soil to soil, and perhaps different in some degree from the organic matter of soils of older formations.

SOIL SURVEY.

Samples of soil from the various sections of the islands are being collected from time to time, and chemical and physical analyses are being made as fast as opportunity permits. This work will be continued until the soils from all the important upland districts have been systematically examined. Previous classifications of the island soils have been of a very general nature, and, with the exception of the sugar lands, no systematic effort has been made toward the classification and grouping of the soils. With the advance of diversified agriculture into the previously unoccupied lands, information concerning the composition and properties of these soils becomes of greater importance. A classification and survey of these soils in the sense it is understood in older countries may never be possible, but a general survey and location of local types and the study of their properties will undoubtedly be of great use to future agriculturists.

In this work new and rare types have already been discovered. In addition to the highly manganiferous soils of Oahu, the occurrence of an extensive body of highly titaniferous soil has recently been found. Samples have been analyzed which, in some instances, contain 20 per cent titanium, expressed TiO_2. This soil has peculiar properties which are of both practical and scientific interest. Other sporadic soils having abnormal properties have also been found. Sufficient data have already been accumulated, therefore, to justify the conclusion that the upland soils of the several islands present a range of variation in composition and properties by no means common on such limited areas.

FERTILIZER EXPERIMENTS WITH COTTON.

In cooperation with the agronomist, fertilizer experiments with cotton have been conducted for the past two years. The results obtained are fairly concordant and will perhaps be of some interest to the cotton growers of the islands. These experiments were conducted on the lands of the Kunia Development Co. and the upper portion of the Oahu Sugar Co.'s land, both on Oahu, and in each instance dry-land culture was employed without the use of artificial irrigation. The small yields are in part due to the lack of sufficient moisture, and the effects of the several fertilizers, while relatively striking, would no doubt have been greater under more moist conditions. Fertilizers to be of the greatest benefit require an abundance of moisture in the soil. In some instances the application of fertilizer to pineapples at the beginning of a dry season produced little effect, and examination some weeks later showed the fertilizer to be apparently unchanged in the soil. In other instances near by a similar application, when followed by sufficient rains, brought about excellent growth. The Seabrook strain of Sea Island was used in these experiments with the following results:

Yields of seed cotton in fertilizer experiments.

Fertilization.[1]	Size of plat.	Kunia.		Waipahu.			
		1909		1909		1910	
		Yield per acre.	Increase per acre.	Yield per acre.	Increase per acre.	Yield per acre.	Increase per acre.
	Acre.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Check	3/40	240		119		147	
Superphosphate, sulphate of potash	3/40	347	16	218	88	220	105
Dried blood, superphosphate	3/40	416	85	217	87	267	152
Dried blood, sulphate of potash	3/40	307		66		103	
Check	3/40	320		66		83	
Dried blood, superphosphate, sulphate of potash	3/40	470	139	278	148	257	142
Ammonium sulphate, superphosphate, sulphate of potash	3/40	480	149	440	310	190	75
Nitrate of soda, superphosphate, sulphate of potash	3/40	450	119	572	442	313	198
Check	3/40	353		161		100	
Dried blood, basic slag, sulphate of potash	3/40	453	122	356	226	263	148
Dried blood, dicalcic phosphate, sulphate of potash	3/40	490	159	546	416	352	237
Dried blood, superphosphate, sulphate of potash, lime	3/80	587	256	665	535	353	238
Lime	3/80	427	96	197	67	133	18
Check	1/10	412		174		132	

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[1] The fertilizers were applied so as to provide the following quantities per acre: Nitrogen, 20 pounds, phosphoric acid, 50 pounds, and potash, 30 pounds.

From these data it is clear that phosphates are the most needed fertilizing material in these soils and that there is some difference in their relative values. Dicalcic phosphate appears to have been somewhat more effective than other forms. These soils contain considerable phosphoric acid, but it is very largely combined with iron and alumina in extremely insoluble combinations.[1] It is likely that an easily soluble phosphate, like superphosphate, would tend to combine with the iron and alumina of these soils, forming difficultly soluble compounds, to a greater degree than the less soluble dicalcic phosphate. Potash and nitrogen, unless applied in conjunction with phosphates, produce little effect, and on the Waipahu experiment nitrate of soda was more effective than other forms of nitrogen. Lime likewise was ineffective when applied alone. The greatest yields in each instance were obtained by the combination of lime and a complete fertilizer. The experiment at Waipahu in 1910 was a continuation of that in 1909, the same plats being used in the two years, and the cotton was grown as a perennial. The fertilizer at the beginning of each of these experiments was applied in the furrows before planting. In 1910 the fertilizer was applied in February around the old plants and thoroughly worked into the soil. The total yields do not fully explain the noticeable effects from the treatment, for the plats treated with phosphates came into picking earlier than the others and yielded a greater percentage of their total harvest in fewer pickings than the unfertilized plats. Credit is due and thanks are here extended to Mr. F. G. Krauss and Mr. C. A. Sahr for cooperation in these experiments. The success of the trials was made possible largely as a result of their cooperation.

RICE INVESTIGATIONS.

The fertilizer experiments with rice have been continued as in previous years and with similar results. In these experiments two crops of rice have been grown on the same land each year, and where ammonium sulphate was applied to each crop before planting the yields have been fully maintained. By the application of fertilizer to the spring crop only, however, the yields are gradually becoming smaller. The plats to which no fertilizer has been applied have become so reduced in crop-reducing power that an unprofitable yield is now being obtained.

The experiments with different forms of nitrogen have been concluded and the results published.[2] In these experiments it was shown that ammonium sulphate is a suitable fertilizer for rice, but nitrate of soda is ineffective. By the use of pot experiments it was determined that rice absorbs nitrogen largely from the ammonium form and that if nitrates constitute the only form of combined nitrogen accessible to rice poor growth and unhealthy plants result. Rice appears not to have the power properly to transform nitrates into proteids.

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[1] Jour. Indus. and Engin. Chem., 2 (1910), p. 277.

[2] Hawaii Sta. Bul. 24.

INFLUENCE OF MANGANESE ON PLANTS.

The investigation on some of the functions of manganese in plant growth have been continued throughout the year, and the results are being prepared for publication in a bulletin on this subject. In this investigation it has been found that manganese affects the mineral balance in practically all plants examined, and causes the plants to take up an abnormal amount of lime and smaller amounts of phosphoric acid and magnesia than are absorbed normally. Not all plants are equally sensitive to manganese, and a number of species show no visible effects from it. Further discussion of this question is reserved for the subsequent publication.

REPORT OF THE AGRONOMIST.

By C. K. McClelland.

In the agronomy division experiments with rice and with cotton have continued to be the principal work undertaken, while those with alfalfa, soy beans, peanuts, and other legumes, also with corn and sorghum, have been of secondary importance. During the year the retiring agronomist prepared a bulletin upon Leguminous Crops for Hawaii, and also a press bulletin upon Peanuts in Hawaii.[1]

RICE EXPERIMENTS.

The work continues with rice because of its importance in Hawaii, and with a hope that in the near future locally grown rice may regain the former importance in home consumption which it seems to have lost. Attention is called to the fact that rice is the only subsistence product raised in large amounts which is consumed by the "foreign" class of people, which class greatly outnumbers the native or taro-consuming class. So that if at some future time imports into the islands should for any reason be cut off, the rice crop would be the means of preservation of the foreign population, which without rice would, so to speak, be threatened with starvation. As noted in previous reports, the conditions surrounding the rice industry are very peculiar, in that, though the Chinese are the principal growers of rice, the Japanese are by far the largest consumers, and as they prefer Japan rice the imports of rice from Japan increase yearly.

The reasons given for this in the 1908 report were lack of flavor, strength, richness, or fattiness in the Hawaiian-grown rices, even in Japan varieties produced here. Chemical analyses made by the Bureau of Chemistry of the United States Department of Agriculture show that what little difference there is in composition is in favor of the Hawaiian rices. Another reason given the writer is to the effect that upon cooling the Hawaiian rices fall apart and become dry and rubbery, while the Japan rice, which in cooking also retains its individuality of kernel, upon cooling is held together and does not become dry and rubbery. Furthermore, the Japanese, being a very loyal people, prefer to spend their money in helping their countrymen who are the growers, importers, and transporters of this rice.

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[1] Hawaii Sta. Bul. 23 and Press Bul. 29.

Whatever may be the reason, the actual facts are that Japan rice is consumed by the Japanese and in smaller amounts by the whites; while the Hawaiian Gold Seed or Chinese varieties are consumed by the Chinese and whites or shipped to California for the Chinese there.

In order to procure, if possible, a rice that would satisfy the taste of the Japanese consumers, the former agronomist visited Japan and brought back several of their better varieties which have now been grown at the station through three generations. The following table shows a comparison in yields between these and a former importation which has been grown here for several years but which seems to have deteriorated in quality:

Yield of Japanese varieties of rice grown at the station.[1]

Varieties.	Spring, 1910.	Fall, 1910.		Spring, 1911.
		Fertilized.	Unfertilized.	
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Benkei	4.00	20.00	18.00	63.25
Miyako	3.75	19.00	18.25	74.75
Omachi	4.87	18.00	20.00	95.25
Shinriki	4.23	24.00	20.50	82.50
No. 153 (old variety)	4.15	14.25	11.75	100.00

[1] The areas were different for different seasons, but the same for all varieties for each season.

Of these rices the Miyako is the only one which has been produced in sufficient quantity for a culinary test. A resident of Honolulu who lived for many years in Japan reports this rice, as grown in Hawaii, "to cook as well as the imported Japanese rice, and, also, when cold, it keeps its moisture, which the Hawaiian does not do. It has not the oily strength of the native Japanese rice, but in taste and appearance quite equals, I think, the native rice of Japan." By another year it is hoped to have had all of these varieties tried out and thoroughly tested by the Japanese themselves.

In the spring crop of 1911 two variations were noticed from the growth of these rices: The Benkei variety developed a heavy tillering habit, which the Shinriki seems to have lost; and the Omachi, which is a bearded rice, was almost entirely beardless. If the latter rice will not deteriorate in quality under Hawaiian conditions it will no doubt be the rice to grow in these islands. Small lots of seed of all these rices were given to several growers, but it is difficult to get any of them to undertake any experiment with small lots of seed.

For the fall crop of 1911 a considerable quantity of the Omachi and of the Shinriki have been put out for trial, and a test of these can soon be made. The old variety, No. 153, was a selection from an importation made from Japan by a Chinese rice grower. This rice, as before stated, seems to have deteriorated in quality in the several years during which it had been grown in Hawaii, and because of this and partly for other reasons enumerated above, it has sometimes been sold at a loss to the producer, which fact has discouraged the Chinese growers, until it is very difficult indeed to get them to test any other Japanese variety, fearing a like result.

Ten varieties of Formosan rices were received for trial and were given their first test in the spring of 1911.

An experiment in planting 1, 2, 3, 4, and 5 seedlings in a clump resulted in nothing definite, as a different number proved the best in each different variety tried.

The fertilizer and rotation experiments with rice are being continued in the same manner as mentioned in the previous report.

COTTON EXPERIMENTS.

Because of the awakened interest in cotton the station has continued experiments with this crop along the lines mentioned in the previous report. The work with the Sea Island and Caravonica varieties has been of the greater importance, although that with other varieties has been no less interesting. It would seem from the experience with the cotton crop that the thing, more than all others combined, which will determine whether or not cotton is to be a profitable crop in Hawaii is success in controlling insect pests. Cutworms eat off the young seedlings, aphids cover and by their voracious attack stunt the young plants; then when in bloom the mealy bug, the cotton bollworm, and the leaf roller become serious pests.

COOPERATIVE EXPERIMENTS.

The cooperative experiment at Waipahu was planned as a fertilizer test in 1910, but some of the results showing a comparison of varieties may be given here:

Comparative yields of cotton.

Varieties.	Area.	Yield of seed cotton.	Yield of lint.	Percentage of lint to seed cotton.
	Acres.	*Pounds.*	*Pounds.*	*Per cent.*
Sea Island	1	202.66	54.66	27
Caravonica	1	66.12	25.37	38.37
Egyptian	1	343.75	115	33.4
Chinese upland	1	546	180.83	31.1

It will be noticed that all of the yields are rather low. The upland, as one would expect, shows the greatest yield, and the Sea Island, which one would look for in the lowest place, outyielded the Caravonica. By referring to the previous annual report it is found that the Caravonica gave the lowest yield in the first year of these tests and also in a similar one at Kunia.

The location seems to have been unfavorable for cotton, as there was only about 40 per cent of a stand reported, and of that the bollworm is said to have taken 30 per cent. It was noticed that the damage was considerably less upon the upland than upon the other varieties. In another experiment with Caravonica transplanted seedlings gave much better results than those not transplanted.

EXPERIMENTS WITH CARAVONICA COTTON.

About an acre of land at an elevation of 250 feet was planted February 4 and 5, bloomed by July 1, and was picked in six and eight pickings between October 1 and December 24, the bollworm infestation varying from 5 per cent in the third to 15 per cent in the sixth picking. The results were as follows:

Yield of Caravonica cotton.

Number of plants.	Yield of seed cotton.	Number of bolls per pound.	Yield of lint.	Percentage of lint to seed.	Length in 16ths inch.
	Pounds.		*Pounds.*	*Per cent.*	
628	424.12	90	153.25	30 to 37	21 to 30
1	[1] 0.67	60	0.244	[1] 36	[1] 24
[2] 680	469.8	....	165.9	....	....

[1] Average. [2] One acre planted 8 by 8 feet.

These results, as calculated to a full acre, show quite an improvement over those at Waipahu, although only in the first year, when Caravonica is noted for its shy bearing. The length and the percentage of lint are very good, while an average of only 90 bolls to the pound of seed cotton is unusually low. This cotton was grown on the station grounds in a place quite well protected from the wind, which indicates that much better returns are to be expected when this variety is planted in protected places.

PRUNING OF CARAVONICA COTTON.

From December 5 to 8, after the sixth picking, 312 of these plants were cut back very severely; some high pruned at about 4 feet and others low pruned at about 2 feet. From the pruned branches the cotton was picked as it matured. Strength tests of fibers thus matured and picked show a gradual weakening of the fiber; i. e., the more immature the fiber or boll at pruning time the weaker the fiber in comparison with fibers matured upon the plant in the natural way.

The balance of the field was pruned back the first week in March of the present year to test the effect of different dates of pruning. The December pruning made a vigorous growth in the spring and pinching was done upon both the high and low pruned trees (leaving some as checks in both instances), some at squaring time, and upon others not until the flowering stage. A pruning test of the Caravonica cotton and an extensive cooperative experiment have been attempted upon the plan and theory given below.

Seedlings are to be pruned when about knee high—this checks the leading stem and induces branching. The first branches are usually vegetative branches and from these grow out the fruiting branches proper.

To induce these and also to check the vegetative branches the latter are pruned when it is thought that sufficient growth has been made. Other fruiting branches spring from the first ones, and an occasional pinching back is thought to favor the production of fruiting wood and thus of squares, and at the same time to restrain the tree-forming tendency. (See Pl. VI, figs. 1 and 2.) The results of this pruning were well demonstrated in the field of Caravonica, where the shape of the trees has been determined and the size largely controlled by this method, while squares were formed earlier and in greater abundance. However, the attacks of the bollworm have been so great that a comparison of the final results will not be conclusive. As a result of their work it is safe to say scores of squares, blooms, or small bolls have been shed, and many of those that escaped at first ripened prematurely as the result of a later attack.

There seemed to be two distinct squaring periods in these plants during the spring months, with an interval of perhaps 35 days between. At the first picking, made about June 1, the percentage of bolls infested by bollworms averaged 68 per cent. It was thought that by giving the plants an annual cutting back, as described above, the bollworm could be held in check, and the infestation soon fell to about 20 per cent.

Later information upon this point is to the effect that the idea of controlling the bollworm by an annual pruning is in the main correct, but the partial failure this year to accomplish the desired result is due to the fact that the prunings were made at different times, thus allowing a breeding place for the worm, first at one side of the field and then at the other. To make the work effective the pruning should be done over a large area at the same time and the prunings burned at once to destroy the larval and pupal stages of the insect. Any larval or mature form that is left will find no bolls or blossoms in which to feed and will consequently perish.

At Makaweli, upon Kauai, the 1910 crop was mostly destroyed by the worm, following two prunings in the field at different times, while the 1911 crop, which followed one complete pruning and burning, promises to be almost entirely free from bollworm.

Upon the windward side of Oahu also there are three plantings upon a considerable scale which were given this thorough pruning

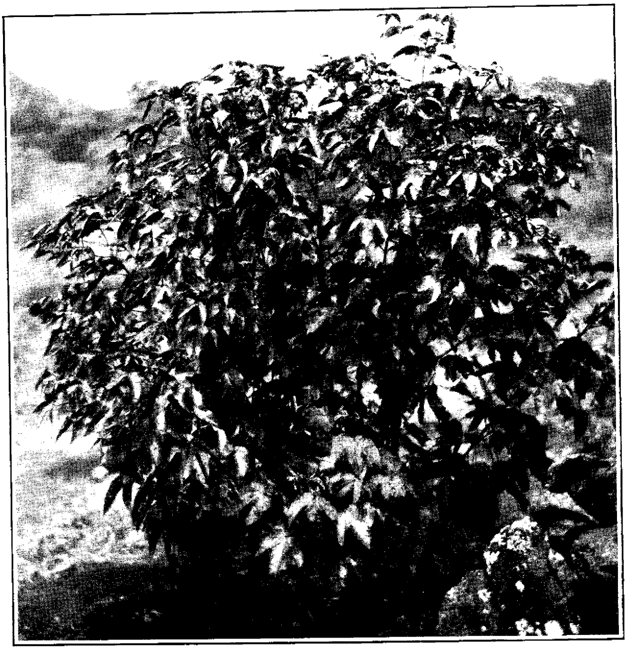


FIG. 1.—PRUNED CARAVONICA COTTON.

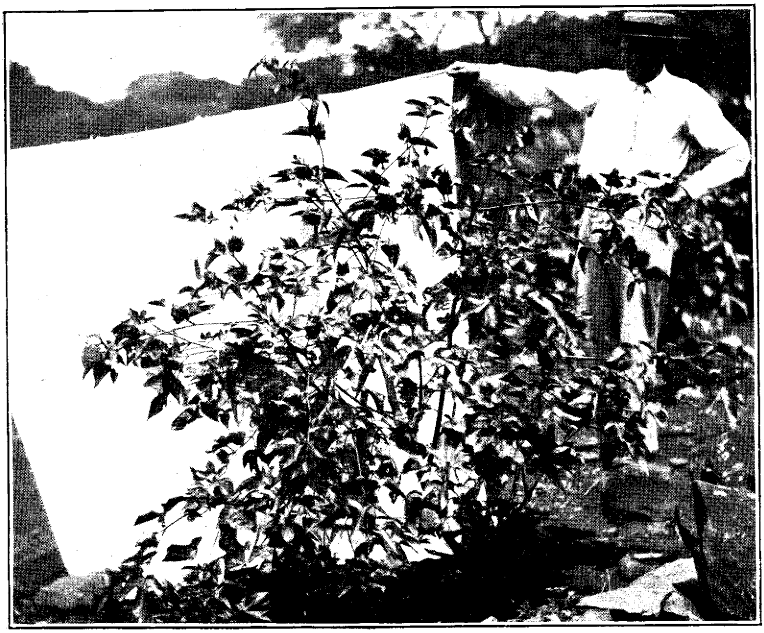


FIG. 2.—UNPRUNED CARAVONICA COTTON.

COMPARISON OF PRUNED AND UNPRUNED CARAVONICA COTTON.

and burning at one time, and all of these are now comparatively free from the insect.

MISCELLANEOUS EXPERIMENTS WITH CARAVONICA COTTON.

To reduce the damaging effects of the bollworm it has been found that the use of a trap, consisting of a lantern elevated above a pan of water and kerosene in the field at night, has been of material benefit, catching as many as 50 moths per night, the greater catch being made upon the stiller nights. By the use of the lantern and by cutting off and burning the infested bolls regularly the percentage of infestation in the field was reduced from 68 per cent in the first picking to 50 per cent in the second and to 26 per cent in the third picking.

Some selections were made from the field mentioned above and the yields from the individual plants were as follows:

Yield of Caravonica cotton plants.

Plant No.	Number of bolls.	Yield of seed cotton.	Yield of lint.	Percentage of lint to seed.	Length in 16ths inch.
		Pounds.	*Pound.*	*Per cent.*	
0	281	1.92	0.63	32.9	24
1	65	.9	.33	37.1	21
2	149	1.42	.48	33.5	25
3	211	1.64	.57	34.7	26
4	203	1.87	.68	36.3	22
5	449	3.26	.98	30.0	30
6	331	2.79	.99	35.6	24

A study of this table shows great variation in yield, in percentage of lint, and in length of staple. However, each plant showed a marked superiority over the average run of plants in the field. Selection "0" shows a trace of Egyptian blood and selection "5" a trace of Sea Island, indicating the mixed parentage and great variability of Caravonica cotton.

As showing the possibilities of Caravonica, the following results will be of interest:

Yield of individual Caravonica cotton plants.

Row.	Plant No.	Number of bolls.	Yield of seed cotton.	Yield of lint.	Percentage of lint to seed.	Number of bolls per pound.
			Pounds.	*Pounds.*	*Per cent.*	
26	1	569	6.56	2.73	41.6	87
26	2	446	4.23	1.72	40.6	105
26	3	300	2.73	1.12	41.2	110
28	1	602	5.61	2.28	40.6	107
28	2	323	3.04	1.28	42.1	106
28	3	189	1.65	.67	40.6	114

The results are from 2-year-old trees grown but a few feet above sea level, the plants having the number "1" in each case, of course, being outside plants and located also upon the leeward side. (See Plate VII, fig. 1.)

EXPERIMENTS WITH SEA ISLAND COTTON.

A small planting of 50 plants of this cotton was made upon the station grounds on February 10, 1910. These plants were in bloom by June 1 and the crop was picked in four pickings made on August 24, September 15, October 4, and October 31. The heaviest picking was made on October 4. The results were as follows:

Yield of Sea Island cotton.

Number of plants.	Number of bolls.	Yield of seed cotton.	Number of bolls per pound.	Yield of lint.	Percentage of lint to seed cotton.	Length in 16ths inch.
		Pounds.		*Pounds.*	*Per cent.*	
49	8,633	52.5	164	11.12	[1] 21.2	26–31
1	[1] 176	1.07		.227	16–33	[1] 30
[2] 1,742		1,864		395		

[1] Average.

[2] One acre planted 5 by 5 feet.

One plant was taken out during the season, so that the record shows for only 49. If this is a fair example of what may be expected of Sea Island cotton there are doubtless other crops now grown in the Territory that are less profitable. The loss due to insects was estimated at about 20 per cent, which would reduce the yield by that much.

EXPERIMENTS IN PRUNING SEA ISLAND COTTON.

The last day in December these plants were pruned back to mere stumps, some being pruned high and some low. New growth started out in all cases from near the ground, signifying that when growing Sea Island as a perennial the plants should all be low pruned. From the start the plants have grown well and fully occupied the space allowed them. It may be that when grown as a perennial it will be necessary to plant it 8 by 5 feet rather than 5 by 5 feet to allow sufficient room between the rows for ease in cultivation and picking. The plants bloomed profusely in the spring and promised an early summer crop, much of which, however, was shed, owing primarily to the attacks of the bollworm. Several of the plants also were attacked by mealy bugs so severely that it became necessary to destroy them.

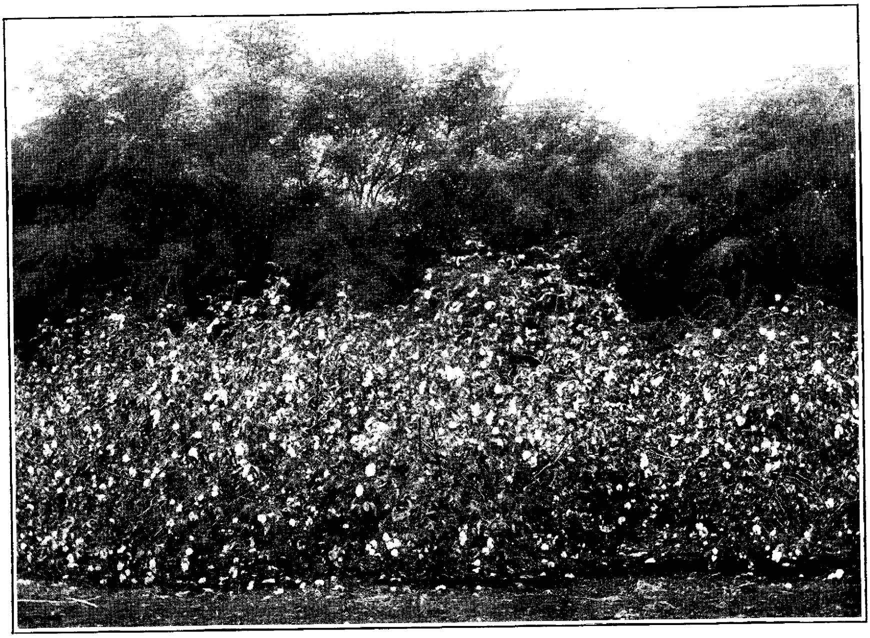


FIG. 1.—CARAVONICA COTTON YIELDING 2.6 POUNDS OF LINT PER PLANT.

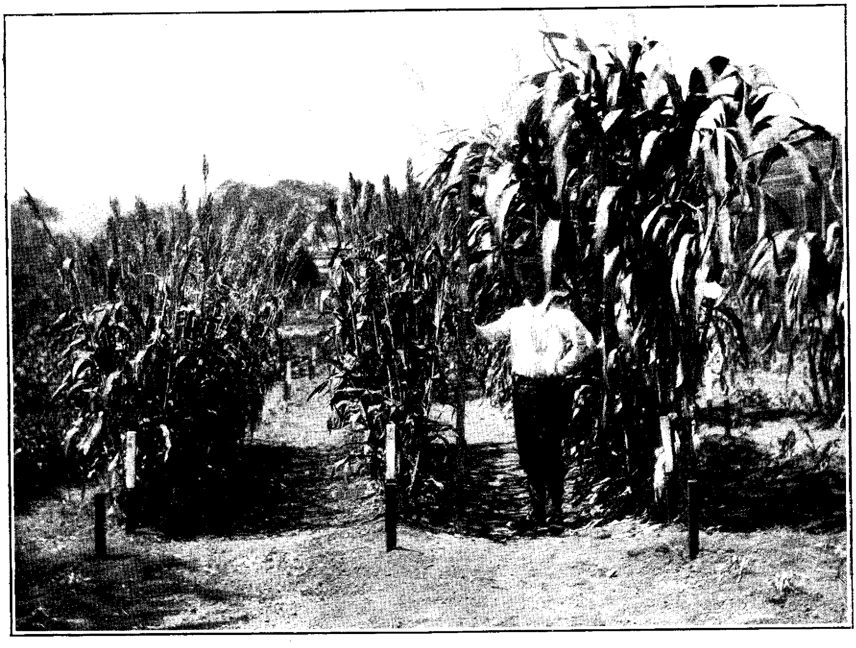


FIG. 2.—RUST-RESISTING SORGHUM AND AMBER SORGHUM.

No additional pruning was given the plants except that a few were pinched back just preceding squaring time, the effect of which was to cause the plants to bloom more profusely and a few days earlier than those not pinched. The first picking in 1911 was made June 15 and the percentage of infestation was very great, showing the prevalence of the bollworm at this time.

MISCELLANEOUS EXPERIMENTS WITH SEA ISLAND COTTON.

From these plants a number of selections were made and the seed from these used in planting a new field of 1 acre upon the slope of Punchbowl. Before the first planting was finished it was washed out by heavy rains, and the second was made March 14 and 15, the hills being placed 5 by 5, as in 1910. Because of the damage to young seedlings from cutworms, a small amount of poisoned bran was spread about the hills in a small circle, which method has proved to be effective. Several seeds were planted in each hill in order to insure a stand and the poorest were weeded out at a later date. This field has shown great uniformity in growth from the start, and, although badly damaged by a windstorm on June 8, promises some good results by the end of the year. The presence of bollworm was noted in the field when in early bloom. A heavy spraying of arsenate of lead was made over a dozen rows to determine what effect, if any, this would have in checking the work of the bollworm.

Aside from the station plantings there have been a few small patches of Sea Island put in in various parts of the Territory. The only plantings of any considerable extent are at various places in Kona, Hawaii. In this district there is a Japanese cotton growers' association whose members have planted, or are planting, an area of about 500 acres. The climate and general conditions for the growth of cotton here are said to be better than at any other point, or in any other district in the Territory.

COTTON FIBER TESTS.

The tests of Caravonica cotton fiber from pruned branches were mentioned above. It might be added here that these fibers were of smaller diameter, but of equal length with those matured upon the plant, and the breaking strength dropped from 8.99 grams to 6.24 grams. Some Mexican cotton grown at Kunia had an average strength of 8.54 grams, but the United States Department of Agriculture reports it as being less uniform than any cotton ever tested there.

Some samples of Caravonica cotton submitted from Kunia showed, from ginned cotton an average strength of 9.3 grams, while the unginned showed 11.3 grams, which at the time this was reported was the highest strength test on record.

Sea Island cotton from the same source but which was picked from some plants that had been pulled (and consequently had immature fiber) was submitted to the Clark Thread Co., which reported rather unfavorably upon it, saying it contained a large quantity of immature fiber and nep, excessive waste, and the yarn produced was too weak for thread. Former reports of Sea Island cotton were more favorable and no doubt, as stated, this failure to make good was due to the immature fiber.

When it is considered that the average strength of Big Boll American upland is about 7 grams and of long staple varieties between 4 and 5, the value of Caravonica cotton from Hawaii is readily seen, and the need for every encouragement which can be given for its production is quickly understood.

MISCELLANEOUS CROPS.

In Hawaii the areas suitable for cultivation in the staple crops, like cane, rice, and pineapples, are fairly well defined, and the problem is to find a profitable crop for the remainder of our lands.

With this end in view, experiments were made to determine the profitableness and the limitations of cotton. Because of the use of large quantities of soy beans in the manufacture of "soy sauce" it would seem that soy beans would be a profitable crop and should be grown here rather than imported from Japan. The experiments with peanuts show that they thrive and do well here, and it may be that a peanut industry upon a large scale would be a profitable undertaking, and especially so if a number of growers in the same community could grow a sufficient area to make the erection of an oil or peanut-butter factory of some object to capitalists. One man who is experimenting with cotton has planted a quantity of peanuts in rows between the rows of cotton, insuring himself, as it were, against loss by a possible failure of the cotton. He and some others report also the growing of watermelons in like manner and at good profit.

As some interest is being shown about Honolulu in the broom industry, the station is carrying on some work with broom corn. In 1910 several rows were grown. The results calculated to acre yields show 95.4 pounds of brush from the lowest yielding row, and 501.6 from the highest. These results are rather low, as yields as high as 1,000 pounds per acre are reported from different places in the States, although, of course, average yields are not far above 500 pounds. Three plantings of corn were made again in 1911 in order to continue the test and get more complete results. This industry will probably be limited to the supplying of the local demand.

Apparently another opportunity for success upon a limited scale is the growing of sorghum and making of sorghum sirup for the

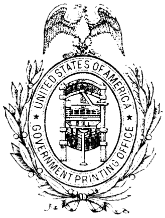
Hawaiian trade. At present the only sirup upon the Honolulu market is a corn product with "cane flavor." The sweet sorghums do well here, although attacked in the later period of their growth by rust. Quite heavy yields can be obtained, and as several ratoon crops can be grown during the year and from one seedling, 1 acre of sorghum ought to produce 1,200 to 1,500 gallons of sirup annually. Tests made upon the fourth ratoon crop this spring with only a partial extraction of the juice gave 31 per cent of juice from the stripped cane, and from this was extracted 12.1 per cent cane sugar and 2.6 per cent of invert sugar. These figures compare very favorably with those given by experiment stations in the South. This crop was grown in 90 days from the previous cutting. In view of the fact that but very little experience is necessary to learn to make the sirup; that very little outlay is required for equipment with which to make it; that no risk is run, since the leaves, tops, or grain, and the pressed canes can all be used for feeding, thus paying for the expense of raising the crop, it would seem that many Hawaiian farmers might undertake sorghum sirup making with advantage.

In connection with the above-mentioned production of forage the station has tested a number of varieties of sorghums, both saccharin and nonsaccharin. A number of these were of African origin, and from among these one was found that greatly exceeded the others in yield, while at the same time it proved to be nearly or quite rust proof. (See Plate VII, fig. 2.) The station hopes soon to distribute seed of this and thus introduce a valuable addition to our forage plants.

Soy beans, jack beans, cowpeas, velvet beans, and alfalfa were discussed in Bulletin No. 23, and require no further report here.

Another new legume, Guar, has been received from the Department of Agriculture at Washington, and its growth is very promising. Planted in rows 5 feet apart and from 2 to 6 inches in the rows one variety gave $1\frac{1}{4}$ tons to $2\frac{3}{4}$ tons per acre of air-dried forage and from 1,190 to 2,610 pounds of seed. Another variety gave yields of both seed and forage with extremes within the limits shown by this variety.

The 1910 corn trials, which included Black, Yellow Flint, Reid Yellow Dent, Boone County White, and Ensilage Pamunkey, showed the last variety and the Yellow Flint to be the better under Hawaiian conditions. In the spring of 1911 Yellow Flint and two varieties from Bolivia, Cusco and Black, were planted at the trial grounds, but were destroyed by insects. A larger planting of Yellow Creole received from New Orleans was made at a later date at the station, and at the present writing is very promising.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HAWAII AGRICULTURAL EXPERIMENT STATION,

E. V. WILCOX, Special Agent in Charge.

ANNUAL REPORT

OF THE

HAWAII AGRICULTURAL EXPERIMENT STATION

FOR

1912.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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J. DE C. JERVES, *Superintendent Homestead Substation.*
J. K. CLARK, *Superintendent Waipio Substation.*

LETTER OF TRANSMITTAL.

Hawaii Agricultural Experiment Station,
Honolulu, Hawaii, July 15, 1912.

Sir: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year ended June 30, 1912.

Respectfully,

E. V. Wilcox,
Special Agent in Charge.

Dr. A. C. True,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. True, *Director.*

Publication authorized.
James Wilson,
Secretary of Agriculture.

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ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1912.

SUMMARY OF INVESTIGATIONS.

By E. V. Wilcox, *Special Agent in Charge.*

BUILDINGS AND GROUNDS.

As the work of the different members of the station staff continues, new conveniences are required in the station buildings for special purposes. Many interior changes have been made to better meet the new requirements. In addition to interior alterations most of the buildings have been repainted and otherwise repaired in order to protect them more fully against injurious effects of the weather, which are particularly noticeable under tropical conditions. A glass house has been erected for propagating purposes, and the old one, which had become quite unsuited to our purposes, was torn down and partly used in the construction of the new glass house. This structure is made proof against ants by means of cement pillars standing in water. Arrangements for bottom heat in the main propagating bed have been made by means of circulating water which is heated by sunlight in an outside tank. An additional workhouse has been erected for the use of the horticultural department. This contains rooms for seeds, fruit, storage of spraying machinery, and for general inside work purposes.

The trial grounds, which have been used for rice experiments and certain other field tests for several years, could no longer be leased by the station, and in order to continue experiments with rice and with certain other crops, such as cotton, taro, and soy beans, another similar area of about 2 acres near Nuuanu Avenue will be leased for use during the next few years or as long as such experiments seem necessary. With the extension of the cultivated areas on the various substations it has been found possible to carry on such field experiments as were necessary under better conditions than could be obtained on the irregular and sloping soils of the experiment station grounds. Comparatively small areas, therefore, on the main station grounds have been put under cultivation in addition to those which had been so used in previous years. A few acres of shallow soil underlain with partly cemented cinder-rock were planted to pigeon peas and jack beans for the purpose of increasing the supply of seed of these crops to be distributed. The yield was fairly good, although the year has been excessively dry and no irrigation was possible on this particular area. On the 2 acres of ground on Magazine Hill belonging to the experiment station no attempt has been made to introduce a water supply by pipes or otherwise, since it has been decided to use this land only in testing drought-resistant qualities of certain grasses, forage plants, and cottons. The test during the present year has been unusually severe on account of the great length of the season of drought.

CHANGES IN THE STAFF.

During a portion of the year Mr. W. P. Kelley and Miss Alice R. Thompson were absent on furlough, carrying on special studies at the University of California and Columbia University, respectively. Mr. F. A. Clowes was appointed in charge of the Hawaii substations, Mr. W. A. Anderson, in charge of the rubber substation at Nahiku, Maui, Mr. J. de C. Jerves, in charge of the Homestead substation on Kauai, and J. K. Clark, in charge of the Waipio substation on Oahu.

DEMONSTRATION FARMS.

The work inaugurated on the demonstration farms has met with satisfactory success. At the small substation in Hilo attention has been devoted chiefly to the study of varieties of taro, the various methods of propagating these plants, the effect upon yield from planting at different distances apart, and the results obtained from the use of different combinations of fertilizers. Gradually, also, a collection is being made of the known taro varieties for the purpose of determining which names are synonyms and which varieties can really be distinguished by persistent horticultural characteristics. The results of the taro work at Hilo will be ready for publication in the near future. In addition to the taro experiments at Hilo, attention has been given to banana cultivation, particularly in determining the proper planting distance to be used in that climate and in determining the differences between what seem to be two strains of the Bluefields variety.

At Glenwood, where the station has control of 15 acres of land, a more pretentious equipment has been secured and a much greater variety of experiments is being carried on. The neighborhood of Glenwood seems to be best adapted to dairying, and for this reason a dairy equipment has been secured for the purpose of determining the various conditions which will conduce to the largest profit from butter making in that locality. A great variety of forage plants is being tested out, and the equipment of modern butter-making machinery will enable the substation to produce butter for sale on the Honolulu market. One of the objects of the dairy work at this substation is to bring the various dairymen together for the purpose of ultimately establishing a cooperative dairy association among them which can take over the practical work along this line and secure to its members greater profits from butter making than are now secured.

The soils of the Glenwood station are of peculiar character and require special study to overcome the unfavorable effects of excessive rain and lack of an efficient temperature for plant growth. In order to determine to what extent the unsatisfactory growth of various plants in that neighborhood is due to local climatic conditions, a number of pot experiments have been planned to be carried out on the station grounds in Honolulu with soils taken from the Glenwood substation.

At the rubber substation in the Nahiku district of Maui attention has been devoted chiefly to the use of intercrops between rubber, planting Ceara cuttings from the most heavily yielding trees, the cultivation of awa, the tapping of Ceará, and the extraction of kukui-nut oil. It has been found that awa does not thrive well when planted in cultivated soil without the benefit of shade. Further experiments will be carried on under partial shade of rubber trees or in the neighboring forest. Broom corn planted between young Ceara rubber trees produced a good yield of satisfactory brush. One acre has been planted with 200 cuttings from Ceara trees which had shown themselves to be exceptionally heavy producers of latex. It is hoped that from these a uniform set of trees will be obtained which will all be high yielders. Nearly all possible methods of tapping Ceara have been tested, with the result that the cost of collecting rubber has been greatly reduced below the figures obtained in previous experiments reported by this station. Moreover, the machinery now used in preparing rubber yields a better product with a lower percentage of resin, protein, and ash. It appears that these impurities are reduced in percentage in proportion as the pressure is increased between the rollers of the mangling machine.

On the Homestead substation about 2 acres are devoted to varieties of peaches. This fruit thrives especially well on Kauai and is a favorite tree in the dooryards of the homesteaders. A number of highly recommended varieties of peaches were obtained from Florida for testing at the substation. At present they are doing well. Cultural and fertilizer studies are also being carried on with pineapples, there being 1 acre devoted to this crop at the substation. In addition to peaches and pineapples attention is being given to onions, Irish potatoes, sweet potatoes, corn, and a considerable variety of other garden vegetables. The work of this substation has been almost altogether of a practical nature. It has attracted the attention of the homesteaders on the island, and the superintendent has been able to spread much useful information regarding cultural methods, varieties, spraying for fungus diseases and insects, and miscellaneous information of a practical nature.

At the Waipio substation on Oahu the tests thus far have been for the most part along the line of dry farming. During the past season the drought was so unusually prolonged that most of the crops were put to a severe test. Onions were unable to mature bulbs of marketable size, jack beans grew fairly well even when planted during the progress of the drought, and Irish potatoes, sweet potatoes, sorghum, and broom corn were badly affected by dry weather. Of all the legumes tested at Waipio, the velvet bean endured the drought best. Where no windbreak protection was offered to cotton at Waipio it did not mature a satisfactory crop, partly on account of the cool nights and partly on account of the excessive evaporation of the moisture in the soil during the constant trade winds.

ENTOMOLOGICAL INVESTIGATIONS.

The chief efforts of the entomologist during the year were devoted to a study of the Mediterranean fruit fly, mosquitoes, certain parasites of the cotton bollworm, algaroba bean weevils, and scale insects. The practical work in combating the Mediterranean fruit fly has been carried on under the auspices of the Territorial government. The entomologist and the special agent in charge of this station, however, have been consulted and have taken part in all of the active measures which have been adopted. According to the present plan of the campaign the parasites of the Mediterranean fruit fly and cotton bollworm which it is hoped to obtain in Africa will be handled, bred, and distributed by the entomologist of this station. In addition to the usual breeding experiments to determine the variety of fruits affected by the Mediterranean fruit fly, considerable attention has been given to trapping and to the use of a poisoned spray in combating the fruit fly. A number of trips were also made to the Kona coffee district to ascertain the extent of infestation of coffee with fruit fly, the amount of damage actually done by the fly, and to initiate practical measures for controlling the prevalence of the pests in the coffee orchards.

Some attention was given to the study of the life histories and habits of the three species of mosquitoes which are known to occur in the Territory. The immediate occasion for taking up this work was the fear of a possible outbreak of yellow fever on account of the occurrence of the yellow fever mosquito. It was soon found that the yellow fever mosquito was much less common than (*Stegomyia*) *Aëdes scutellaris*, although the latter species was apparently introduced into Hawaii later than the yellow fever mosquito. Much useful information was collected regarding the habits of all three species of mosquitoes, particularly with reference to the situations under which the larvæ breed.

HORTICULTURAL INVESTIGATIONS.

The energies of the horticultural department have been devoted largely to the study of pineapples and methods of propagating the avocado, mango, papaya, and hibiscus. The importance of the pineapple industry of Hawaii is growing greater day by day. The output of canned pineapples, which it was feared two years ago had almost reached the limit of the market for this product, has been greatly increased, and arrangements are now being made to nearly double the area devoted to pineapples. The demand for canned pineapples has taken all of the product which could be supplied and seems to warrant this great extension of the industry. Pineapples are second only to sugar cane in commercial importance in Hawaii. The quality of the product has remained uniform, owing to the fact that there are only two commercial varieties of pineapples in Hawaii and that these varieties are of quite similar nature. Recent observations, however, indicate that these varieties have become mixed on nearly all of the plantations and that one of them is decidedly inferior to the other. The inferior variety apparently came from Queensland, while the superior one is apparently the true Smooth Cayenne. The growers are gradually eliminating the less desirable variety. A press bulletin[1] covering the various cultural and marketing features of pineapples was published during the year. Continuation of experiments in methods of propagating the avocado and mango has developed the fact that these fruits may be inarched or budded almost with as much facility as is known to be the case with fruits of temperate climates. The difficulties which had hitherto made the propagation of superior varieties of avocados and mangoes uncertain are rapidly disappearing.

Similarly with papayas there is a good prospect now that strains of seed will soon be obtained which will show almost a complete uniformity in product. Hitherto this has been far from the actual state of affairs. Much seed obtained by the method of crossing male and female flowers showed a variation which was difficult to control and the products of which could not in any case be predicted.

On account of the restrictions placed on bananas by the recent California quarantine law, it has been found necessary to take up in a systematic manner the methods of packing, which promise to make possible the shipment of bananas to California without danger from scale insects and without injury to the bananas. At present it is hoped that the cooperation of the steamship companies can be obtained in furnishing facilities for shipping bananas without any packing around the bunches. It will then be possible to inspect the bunches more effectively and conveniently and to avoid the heating and other injurious effects of the various kinds of packing which have hitherto been used.

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[1] Hawaii Sta. Press Bul. 36.

During the coming year it is hoped to bring some of the work which has been in progress with hibiscus to a conclusion and to publish the results in bulletin form.

CHEMICAL INVESTIGATIONS.

One of the chief lines of work carried on by the chemical department has been a study of the function and distribution of manganese. Some of these results were published during the year in bulletin form.[1] The work of the station on manganese soils is being closely followed by pineapple growers. It appears impossible by any method thus far adopted to grow pineapples successfully on soils which contain more than 2 per cent of manganese. On highly manganiferous soils not only do the leaves turn decidedly yellow or even whitish but the fruits are pink rather than of the normal color and are too acid or otherwise disagreeable in flavor. In selecting new areas for the extension of the pineapple industry the prospective growers have had manganese determinations made in order to avoid the areas in which a high percentage of manganese is found.

Evidence is accumulating from time to time of the importance of a reasonable balance between lime and magnesia in the soils of Hawaii. In some soils the ratio is greatly disturbed by the excessive prevalence of magnesia and in others by an excess of lime. Satisfactory results can not be obtained on either type of soil with the majority of crops. Since the chief injurious effect of manganese seems to be in causing plants to absorb too much lime and too little magnesia, a systematic set of experiments has been planned to determine whether the effects of manganese can not be overcome by adding magnesia to such soils. This question will be thoroughly investigated in a series of pot experiments and on a commercial scale in the pineapple fields.

In decorticating sisal a large amount of waste pulp is obtained of which no economic use has been made in Hawaii. A request was made upon the station to investigate the possible utilization of this pulp. The chemical work was done by the assistant chemist and resulted in determining that the greatest practical value of this pulp was for fertilizing purposes. Sisal removes large quantities of mineral plant food from the soil which can all be returned by the use of the pulp as a fertilizer. The pulp will also add a quantity of humus to the soil. One of the striking scientific results of this investigation was the determination of lactic acid as the normal vegetable acid of sisal. The percentage of acid increases from the base to the tip of the leaf. It is not likely that the acid can be extracted from the pulp with profit. The trouble which the presence of the acid has caused in corroding machinery has largely been overcome by the use of gun metal in the place of iron.

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[1] Hawaii Sta. Bul. 26.

A special study has been made of sulphur and chlorin in the rice plant. Many difficulties have been met with in determining the sulphur, and particularly on account of the occurrence of sulphur in gas in the laboratory. This trouble was overcome by the use of alcohol lamps in the place of gas. When ammonium sulphate was used in pot cultures in sterilized silica sand it was found that the assimilation of ammonia and mineral sulphur took place in such proportions as to indicate clearly that the plant takes up ammonium sulphate as such.

In testing the effect of various fertilizer combinations on taro it was found that the best form in which nitrogen can be applied is ammonium sulphate or an organic form of nitrogen. The effect of nitrate of soda was in some cases equally marked in so far as the total yield was concerned, but it required a much greater weight of taro to produce the same amount of poi when nitrogen was applied as nitrate of soda.

A special examination of Hawaiian soils is being made for the purpose of determining the form in which nitrogen normally occurs in the soil. It appears from preliminary work that the amount of ammonia in certain soils may be 100 times that of nitrate. This problem is of great importance in the rational treatment of our soils, and its study will be continued during the coming year.

Chemical work on various rubbers has been prosecuted in cooperation with the rubber substation on Maui. In addition to work in determining the percentage of resin, ash, protein, and true rubber gum in Ceara and Hevea rubbers, a study has been begun of a new rubber product from *Euphorbia lorifolia*. This tree covers an area of about 6,000 acres in the Kona district of Hawaii, and yields a large quantity of latex, which can be coagulated only by use of heat or alcohol. The dry matter of the latex contains 14 to 17 per cent rubber and about 60 per cent of a resin which appears to be nearly, if not quite, identical with chicle gum.

In cooperation with the Philippine Bureau of Science the chemical department made observations during the year on the actinic power of the sun, with the interesting result that the actinic effect of the sun is highest at the spring and fall equinoxes and lowest at the summer and winter solstices.

AGRONOMICAL INVESTIGATIONS.

Cotton continues to occupy the interest of a considerable number of planters. It has been quite conclusively proved that this crop does not thrive well on the upper lands unless well protected against trade winds nor in any locality where the temperature is relatively low. On the other hand, excellent results in yield and quality have been uniformly obtained at sea level and in protected localities on the leeward side of the various islands. On account of the fact that Caravonica cotton is less susceptible to attack of the pink bollworm than Sea Island there is a tendency to grow Caravonica cotton chiefly. The prices obtained for this cotton have ranged from 18½ to 20 cents, and a report received from one mill states that the fiber is equal to the best rough Peruvian. In actual strength Caravonica lint appears to be superior to all other varieties of which breaking tests have been made. From a comparative test made by a mainland cotton mill it appears that the value of Caravonica lint obtained from the saw gin is so nearly equal to that from the roller gin that the economic considerations are in favor of the use of a saw gin.

Yields obtained from rices imported from Japan have continued to be satisfactory. Milled samples of this rice have been distributed among various inhabitants of the Territory who were interested in comparing their culinary qualities. There is a growing belief that these rices raised in Hawaii from Japanese seed are practically identical with rice directly imported from Japan. A systematic study is being made of the forage grasses of the Territory. In addition to the species which were native to Hawaii and those which were introduced long ago, many species have been brought in from various tropical and temperate climates to test their adaptability to our wet and dry ranges. The experiments have taken various forms. In some cases the seed was simply sown on the range without any previous preparation, being scattered upon the natural sod of the range. On at least one ranch elaborate planting operations have been carried on during which the ground was plowed and thoroughly prepared before seeding. These operations while relatively expensive promise to give economic returns in forage.

MISCELLANEOUS.

Dynamite has been commonly used for many years on the station grounds in preparing soil for planting trees. This has been found to be the cheapest method by which good soil conditions can be given for the extension of tree roots. During the year a special grade of dynamite was tested in plowing heavy soils for pineapples, in loosening the soil about the roots of growing trees, in improving the drainage in lawns, and in furnishing an outlet for water in small sink-like areas in which the surface water tended to collect. These tests have in all cases shown the large range of applicability of dynamite to farming operations and its effectiveness and economy.

Among the unusual feedstuffs which are used in Hawaii mention may be made of honohono, algaroba bean meal, soy bean cake, and tree fern trunks. In the extremely wet district of Glenwood, Hawaii, honohono has been found to be one of the best forage crops for dairy cows. It ratoons readily and rapidly without particularly diminishing the yield if stable manure be spread over the ground as fast as the crop is cut off.

While a special machine had been patented for the preparation of a meal from the algaroba bean, the use of the machine was not pushed in a commercial way and great quantities of the beans were being allowed to go to waste. One of the feed companies of Honolulu has at last made arrangements to secure another machine for grinding algaroba beans. This machine is essentially identical with one of the types of alfalfa meal mills. A very satisfactory product is produced, and arrangements have been made to lease land covered with algaroba and to purchase beans on a large scale. It is believed that this product will to some extent take the place of rolled barley, which is now imported in large quantities into the Territory.

The product remaining from the manufacture of soy sauce is a cake containing a high percentage of the usual nutrients in feeding stuffs. The only disadvantage connected with this feeding stuff is the great amount of salt which it contains. It has been found, however, that this can readily be removed by water, leaving a product which has proved valuable for feeding to pigs.

An analysis was made of the common tree fern trunk which occurs in large areas in the mountains. This trunk is widely used as a pig feed either raw or after being cooked. The greater portion of the trunk is of a starchy nature and is much relished, particularly after being boiled. Near the volcano of Kilauea some of these trunks are cooked by being placed over steam cracks.

Among the lines of investigation which have been undertaken and are still unfinished mention should be made of the disease of chickens caused by the prevalence of Manson's eye worm, the extraction of kukui-nut oil, a general soil survey, a study of artificial breeding methods with bees, and a horticultural investigation of hibiscus.

REPORT OF THE ENTOMOLOGIST.

By D. T. Fullaway.

The entomologist was absent in the island of Guam during the early part of the fiscal year, returning to Hawaii on November 3. The accompanying report covers the entomological work done from that date to the end of the fiscal year—a period of about eight months. The routine work of the office, however, was attended to throughout the year. Among other duties performed, numerous inquiries in regard to insect pests were answered personally or by letter. The insect collections of the station were adequately cared for, much material added, and the whole rearranged in new cabinets (following the arrangement in the Fauna Hawaiiensis).

Investigations undertaken in this period were largely in response to pressing demands of the moment, and little opportunity was enjoyed for systematic study of the more important field-crop pests. Some observations of a miscellaneous nature are subsequently noted.

A threatened epidemic of yellow fever, early in November, made desirable a study of the local mosquitoes, which was undertaken by the station. The investigation extended over several months and disclosed much new and useful information concerning the mosquitoes. In publishing the results of the investigation, the writer desires to acknowledge his obligation to the entomological staff of the Sugar Planters' Station, and especially to Mr. Swezey, for much of the material.

MOSQUITOES.

Three species of mosquitoes are found in the Hawaiian Islands—*Culex quinquefasciatus* (*C. fatigans*), the common night mosquito, and *Aëdes calopus* (*Stegomyia fasciata*) and (*Stegomyia*) *Aëdes scutellaris*, usually referred to as day mosquitoes—all three introduced with shipping within the memory of the Hawaiians. From the focal points of introduction the species have spread generally throughout the islands, and in the presence of the conditions requisite for their development are found everywhere from the coast far up into the mountains. The night mosquito differs greatly from the day mosquitoes not only in habits but in the appearance of the larvæ and the adults, while the two day mosquitoes are generally much alike, with certain small distinguishing characters.

NIGHT MOSQUITO.

The night mosquito is a typical culicine and has a wide distribution in the Tropics of both hemispheres. The localities given by Theobald[1] are: Ceylon, Burma, Straits Settlements, China, East Indies, Japan, West Indies, South and Central America, southern part of North America, Natal, Mombasa, Pemba Island (East Africa), Zanzibar, Egypt, Sudan, British Central Africa, Senegambia, Australia, Mauritius, Seychelles, Sarawak, Fiji, Siam, India, Cape Town, Delagoa Bay, Africa, Honolulu. The exact date of its introduction in these islands is now disputed. The historian Alexander states on the testimony of old residents that it was brought to the islands on the ship *Wellington* in 1826. On the other hand, Kamakau, one of the older Hawaiian historians, states that fleas and mosquitoes were unknown in the Hawaiian group until the arrival of Cook's ships (1778–79), implying that they were introduced then. From the evidence adduced, it would seem that the later date is probably correct. For many years this was the only species of mosquito found here, the day mosquitoes coming much later. The species, as already stated, is found in the mountains as well as along the shore (for the simple requirement of its existence, the presence of standing bodies of water, is a universally prevalent condition), and wherever it breeds in large numbers it is the scourge of all unprotected persons at night. The eggs (Pl. I, 1) of this species are laid in rafts several millimeters long, comprising several hundred eggs placed on end and standing together side by side. The eggs taper slightly toward the upper end, so that the upper surface of the mass is a trifle concave. The raft is laid on the surface of the water and is perfectly buoyant. After a day or two the eggs hatch and several hundred tiny "wrigglers" of less than a millimeter's length emerge from the lower end of the respective eggs. These wrigglers, or larvæ, are structurally fitted for an aquatic life. They assume an upright position in the water with head down, jaws busily sweeping food into the mouth, and the respiratory apparatus, which in this mosquito opens externally through a siphon projecting from the penultimate segment, slightly elevated above the surface film. It spends much of the time at the surface, but occasionally makes excursions to the bottom, especially when disturbed, moving by vigorous contortions of the body. It grows in size, and molts. When several days old it becomes very active, going often to the bottom in search of an abundance of food. After several molts and when 10 to 15 days old and about 5 millimeters long, the larva transforms into a pupa, quite different in form, more consolidated and resembling in shape the adult fly's body. The head and thorax are joined and rather swollen; the abdomen is represented by a tail with swimming flaps. The breathing tubes are now on the back near the head, and the body assumes a position in the water which allows these to protrude through the surface film. The pupa is equally active, but as it does not feed it moves only when alarmed. In two days the mature form emerges, leaving its pupal case behind in the water. These mate, and the cycle is continued. Twelve rearings of this species, including many hundred individuals, gave the following records: Egg stage, 1 to 2 days (mostly 1 day); larval stage, 11 days; pupal stage, 1 to 4 days (mostly 2 to 3 days). This gives an average life cycle from deposition of eggs to adult free flying mosquito of 15 days. It was found (with all three species) that a scarcity of food in the aquaria extended the larval life, which could easily be produced to two or three months, without otherwise interfering with the normal development of the species. This species breeds in fresh as well as in muddy and contaminated water and is the typical mosquito of the mud puddle. It was found in perfectly fresh drinking water, in the more or less brackish water of the duck ponds, in the muddy water of ponds, pools, gutters, drains, and in water contaminated by fecal matter, soap, rubbish, and other extraneous matter; it was found in such small collections of water, in tin cans, cups of flowers, small puddles, that without renewal from some source, the quantity of water present could not withstand the losses of evaporation through the larval period; yet it is able to breed in all of these situations in spite of their disadvantages, provided its physiological activities are not interfered with.

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[1] Monograph of the Culicidæ. London, 1910, vol. 5, p. 383.

The larva (Pl. I, 2, 2a) can be recognized from the following description:

> Length 5 to 6 mm. Dark grayish, head more or less black. Thoracic segments almost as wide as the head, behind the thorax body slenderer and tapering. Anal siphon also long and slender, 1.2 mm. in length, greatest width 0.3 mm. Head more or less cubical, eyes black, mouth brushes as usual. The antennæ are long, 0.5 mm., about one-third the length from distal end the shaft becomes constricted, and in the notch thus formed is set a tuft of hairs; beyond the constriction the shaft is much thinner, and at the tip also there are two or three hairs. The labial plate bears a number of spines. The thoracic and abdominal segments laterally bear tufts of hairs which are longer on the thorax. The last abdominal segment bears a conspicuous ventral brush and dorsally there is a tuft of five long hairs. The siphon has a pair of hair tufts at about half its length, another pair a trifle before, more than a third the length from the proximal end, another pair of small tufts less than a third the length from the distal end and a fourth small pair somewhat before these and moved to one side out of line. There is a row of 13 three to four toothed spines on the siphon extending from the proximal end to the first pair of tufts. The lateral comb on the penultimate segment consists of more than 30 plates.

Attention is called to the shape of the anal lobes in the pupa. (Pl. I, 3.)

The adult (Pl. I, 4) is described as follows:[1]

> Thorax brown, with two distinct dark lines on the denuded surface, covered with pale golden curved scales and with two more or less distinct bare parallel dark lines and three rows of dark bristles, ornamentation variable. Abdomen dark brown to black, with basal white or pale creamy curved bands and white lateral spots; venter white or yellow scaled. Legs dark brown; bases of the femora and coxæ pale, knee spot and sometimes the apex of the tibia with a faint yellow spot; ungues of the female equal and simple; in the male the fore and mid ungues are unequal and uniserrated, the hind equal and simple. Wings with the first submarginal cell longer and narrower than the second posterior cell, its stem variable in length, never less than one-quarter the length of the cell; posterior cross vein distant twice (or more) its own length from the mid cross vein.

In view of Dr. Graham's investigations, this species is believed to be the intermediate host of the sporozoan parasite causing dengue fever.

DAY MOSQUITOES.

The day mosquitoes (*Aëdes calopus* and (*Stegomyia*) *Aëdes scutellaris*) are essentially different in appearance from the night one, and the two would never be confounded. Between themselves there are some striking small differences which distinguish them at once. The white markings on the back (dorsum of thorax) of *Aëdes calopus* are in the form of a lyre, while the marking on the back of *Aëdes scutellaris* is a single white line running down the center. The immature forms also present microscopic differences. The comb in the larva of *Aëdes calopus* is composed of 8 teeth with trifid apices, while the pupa has anal lobes dentate margined. The comb of the *Aëdes scutellaris* larva is composed of 10 unidentate teeth, and the anal lobes of the pupa have hairy margins. The Stegomyia larvæ differ radically from the Culex larvæ in both structure and habits, so that all three species are readily distinguished in any stage of their existence.

The exact date of the introduction of the day mosquitoes is not established, but it is quite certain that they came much later than the culicine and, from all accounts, during the lifetime of some of the present generation.

The habits of the two day mosquitoes are very similar. They prefer clear fresh water; at least, they are found almost altogether, if in natural collections of water, in clear water, never in puddles or polluted water, and while they are found along with *Culex quinquefasciatus* in clear standing water in troughs and other artificial containers they are not found if the water in such containers has become foul or turbid. They are very common around habitations, where the larvæ are usually found in water butts, troughs, or other containers of rain water or uncontaminated faucet water. They are also found in permanent pools along stream beds in the gulches and in water holes in the mountains. The adult fly differs radically from the culicine in habits, since it is almost entirely a day flyer, while the culicine stalks out in the night and can not be induced to bite in the daytime. It is also largely found in dark and shady places; in the woods it rests on vegetation, biting viciously when disturbed; in houses it gets in the dark recesses of the room or its furniture and comes forth from these retreats to bite the exposed parts of the body as soon as one's presence is sensed.

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[1] F. V. Theobald. Monograph of the Culicidæ. London, 1901, vol. 2, p. 151.

The life history of the day mosquitoes is somewhat as follows: They lay their small, black, torpedo-shaped eggs (Pl. I, 5) singly to the number of 40 or 50 on the surface of water, or, according to Dr. H. W. Henshaw, who made careful observations on the mosquitoes here some years ago, on the sides of containers, a quarter of an inch or so above the surface, where the eggs will withstand considerable desiccation (before the rising water floats them off) without its interfering with their hatching. The eggs hatch in five or six days. The larvæ in the water are of very similar appearance to the culicine larvæ, except for the short siphon and untapering body. Their habits, however, are different. They feed very largely at the bottom of containers or along the sides, seem to seek the darkest recesses, and do not come as often to the surface to breathe. For this reason they are a rather difficult mosquito to collect. The larval development is usually completed at the end of from 15 to 20 days, when the larva transforms into a pupa. The pupal development occupies two days, and from the pupa emerges the adult free-flying mosquito, male and female, which mate and repeat the cycle.

AËDES SCUTELLARIS.

The distribution of (*Stegomyia*) *Aëdes scutellaris* as given by Theobald[1] is as follows: India, Ceylon, Upper Burma, Siam, Penang, Perak, Selangor, Singapore, Christmas Island, Amboina, North Borneo, Sarawak, Celebes, British New Guinea and New Guinea generally, Foochow, etc., China, Hongkong, Formosa, Japan, Philippine Islands, Fiji, Pitcairn Islands, Seychelles, Mauritius, Guam (Fullaway).

Eight rearings of this species, including many hundreds of individuals, gave the following records: Egg stage 5 to 6 days, larval stage 15 to 24 days (one record 17 days, another 61 days [larval period protracted by reduction of food]), pupal stage 1 to 4 days (mostly 2 days).

It was found, as many other investigators have claimed, that permitting the adult to suck blood in some way accelerated the forma-

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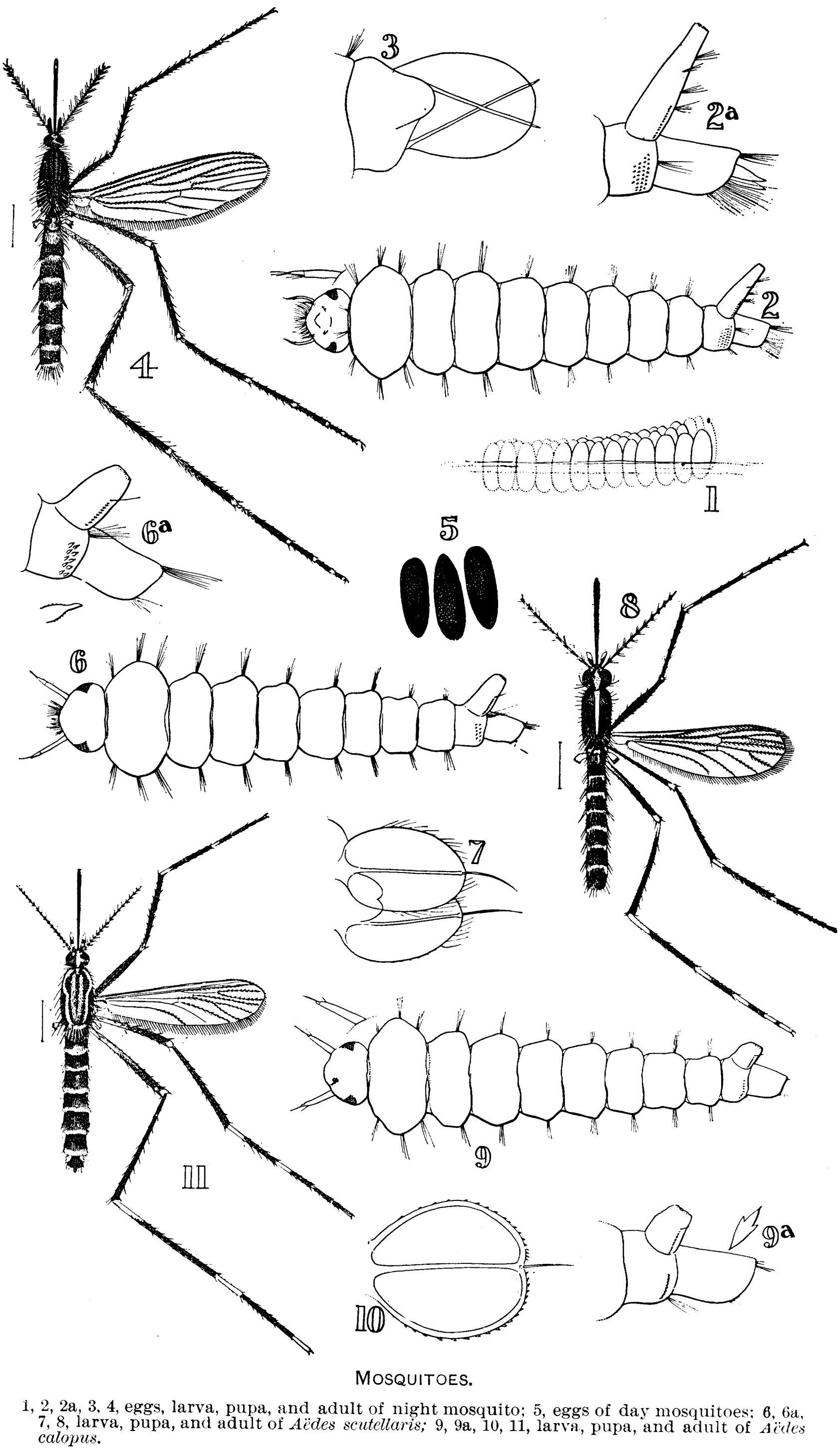
[1] Monograph of the Culicidæ. London, 1910, vol. 5, p. 155.



MOSQUITOES.

1, 2, 2a, 3, 4, eggs, larva, pupa, and adult of night mosquito; 5, eggs of day mosquitoes; 6, 6a, 7, 8, larva, pupa, and adult of *Aëdes scutellaris;* 9, 9a, 10, 11, larva, pupa, and adult of *Aëdes calopus.*

tion and deposition of eggs. All the specimens bred from egg to adult in the laboratory were allowed to feed previous to confinement, and none otherwise confined produced eggs. While this is not necessarily conclusive evidence as to the necessity of this performance to the production of eggs, it corroborates the observations of other workers and the idea seems altogether plausible.

Aëdes scutellaris, like the other mosquitoes in Hawaii, has a very general distribution, but out of the writer's experience the impression was gathered that it is the commoner of the two day-flying mosquitoes, and was always found in great abundance at the mouths of the numerous gulches behind the city of Honolulu in the belt of rising ground occupied by guava, lantana, and klu, where the larva breed in the pools formed by the receding water of drying-up creek beds, the adult flies finding shelter in the thick underbrush. It also breeds commonly around habitations on the outskirts of the city.

The larva (Pl. I, 6, 6a) can be recognized from the following brief description:

Length 6 mm. Grayish, head more or less dark. Thoracic segments almost as wide as the head, the body beyond scarcely tapering. Anal siphon moderately long, 0.72 by 0.36 greatest width. Head more or less cubical, eyes black, mouth brushes as usual, antennæ moderately long, tapering slightly, but of more or less uniform width throughout. A hair on the inner margin at about the middle and a stout spine and several hairs at the tip. Abdominal segments with a pair of hairs caudally on each segment. Ventral brush and dorsal tuft on ultimate segment thin. Pecten on anal siphon with 6 to 13 teeth in a row, the comb composed of 10 unidentate spines with small barbs at base.

Pupa (Pl. I, 7). The hairy margin of the anal lobes is peculiar.

The following brief description of the adult (Pl. I, 8) is sufficient to distinguish the species here:

Throax black, with a median silvery stripe; abdomen with silvery white basal bands; legs black, tarsi basally white banded, last joint of the hind legs pure white.

There is nothing in the literature of mosquitoes to warrant the statement that this mosquito is concerned in the transmission of yellow fever. Its distribution would apparently deny any such claim.

AËDES CALOPUS.

The distribution of *Aëdes calopus* as given by Theobald [1] is as follows: India, Upper Burma, Ceylon, Siam, ports in Malay Peninsula, Philippine Islands, Celebes, New Guinea, Java, Japan, Hawaiian Islands, Fiji, Pitcairn Islands, Samoa, generally in Africa, Southern United States, Mexico, Central America, Panama, west coast of South America, British and French Guiana, Trinidad, Brazil, West Indies, Southern Europe in Portugal, Italy, Spain, Gibraltar, Teneriffe, Greece, Cyprius, Australia in Queensland and Victoria, etc.

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[1] Monograph of the Culicidæ. London, 1910, vol. 5, p. 158.

Three rearings of this species, including many individuals, gave the following records: Egg stage, 4 days; larval stage, 17 days; pupal stage, 2 to 3 days.

This species is more or less rare; at least, in the writer's experience, it is not nearly so abundant as either *Aëdes scutellaris* or *Culex quinquefasciatus.* It was found chiefly around habitations, breeding in artificial containers of rain water or uncontaminated faucet water. Dr. Perkins states that on several occasions he found it in large numbers at rather high elevations, and the specimens on which it was first recorded from the islands were taken in the Waianae Mountains at 1,500 feet. Its distribution is therefore, like that of the other species, rather general, but it is not nearly so abundant as the other two species.

The larvæ (Pl. I, 9, 9a) can be recognized from the following description:

> Length 5 mm. Very similar to *Aëdes scutellaris.* The anal siphon, however, is short and thick, 0.72 mm. by 0.5 mm. greatest width, and its pecten is composed of 10 to 15 toothed spines. The lateral comb of the penultimate segment contains 8 plates with trifid apex arranged in a single slightly curved line.

Pupa (Pl. I, 10). The margin of the anal lobes is distinctly serrate and without hairs.

The following brief description from Theobald[1] will distinguish the adult (Pl. I, 11):

> Thorax dark brown to reddish brown, with two median parallel pale lines and a curved silvery one on each side, a small line in front between the two median ones. Abdomen black, with white basal bands and lateral spots. Legs black, with basal white bands, last joint of hind legs pure white.

The experiments of Maj. Walter Reed, United States Army, in Cuba, proved conclusively that this species is responsible for the transmission of yellow fever, probably acting as the intermediate host of an ultramiscroscopic parasite which produces the disease.

NATURAL ENEMIES OF MOSQUITOES.

There are no known specific parasites of mosquitoes. Among the natural enemies of these insects, which by feeding upon them tend to reduce their numbers, the most efficient are dragon flies and fish. There are several species of dragon flies in Hawaii which as nymphs prey upon the larvæ and pupæ in the water, and as mature free flying insects prey upon the imago or adult mosquito. Among the native fish which feed upon mosquitoes are the different species of gobies, locally known as oopu, which are found in all the streams and small ponds. There are also in Hawaii the introduced gold fish, which is very useful in aquaria, watering troughs, tanks, and other artificial pools containing more or less clear water, and the top minnows (Pœciliidæ), which were introduced some years ago from Texas for the specific purpose of destroying mosquito larvæ. The latter fish have proved very efficient mosquito enemies and along with the dragon flies effectively control the production of mosquitoes in the large low areas near the sea which are devoted to rice and taro growing or covered with the usual swamp vegetation. As the cultivated fields are frequently drained, they must often be restocked with fish. The fish, too, are often checked by the choking up of waterways and in these isolated bodies of water mosquitoes can develop with perfect freedom.

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[1] Monograph of the Culicidæ. London, 1901, vol. 1, p. 289.

REPRESSION OF MOSQUITOES.

Experience has shown that it is economically possible by well-directed efforts to destroy large numbers of mosquitoes in their aquatic stages and considerably lessen their annoyance. The method universally followed is to remove or treat the bodies of water in which the mosquitoes are found to breed. The unlimited details of anti-mosquito work have their foundation and beginning in the accomplishment of this simple purpose. It usually, however, becomes apparent in any work of this sort that many breeding places of mosquitoes have a very temporary existence and are constantly being obliterated, renewed, or altered—such breeding places, for instance, as tin cans, flower cups, or mud puddles—and that these breeding places require constant and continuous attention to effect any real benefit. This militates greatly against the value of sporadic campaigns against mosquitoes. The almost prohibitive expense of the repetition of work which could be done once for all time also enhances the value of permanent drainage of large bodies of water. If future work of this sort is attempted in Honolulu it is respectfully suggested to the public and its authorized agents that part of the funds be set aside for continuous permanent work, such as drainage and reclamation of lowland, rice fields, taro patches, etc.; that ordinances be secured making the maintenance of bodies of standing water in which mosquitoes might breed on premises a nuisance whose continuance would be punishable by fine; and that the funds not used in permanent or absolutely necessary emergency work be conserved to provide for a regular and continuous force of inspectors which would attend to the enforcement of the law as to owners and lessees of premises and look after the otherwise unattended territory to remove all possible breeding places of mosquitoes.

PINK BOLLWORM OF COTTON.

Some attention has been given to the pink bollworm (*Gelechia gossypiella*), which is now recognized as an important factor in the successful production of cotton in Hawaii. A great deal was expected of the cultural methods of control, but after the second year's trial the results seem only partially assuring, where the time and amount of rainfall is variable. One field of Sea Island cotton cut back in December was again in full flower in February and became so badly infested by bollworm that it was necessary to plow up and burn it to save adjacent fields.

In a bulletin[1] of this station the writer recorded the braconid, *Chelonus blackburni*, as a parasite of this species. Several new records are now offered. In a lot of infested bolls brought in in December there were found numerous specimens of a bethylid, believed to be [*Goniozus*] *Parasiorola cellularis*, presumably coming from larvæ of the bollworm. To determine the suspected relationship specimens were confined in breeding jars with larvæ of *G. gossypiella*, and after a short time the bethylid proceeded in its customary manner to paralyze the gelechiid larva and lay eggs upon it. Several generations of the parasite were bred and the length of the several stages noted, as follows: Egg stage 1 day, larva 7 days, pupa 11 days, making the cycle from egg deposition to adult parasite 19 to 20 days. From one to eight eggs were laid on a single caterpillar, but all did not mature. The larvæ usually feed externally, making large holes in the body of the worm, and the development is rather rapid. When full fed they make a small white elongate cocoon (usually spun in clusters where the larvæ were feeding) in which they pupate.

From the same lot of larvæ there were also bred several specimens of the ichneumonid, *Pristomerus hawaiiensis*, previously reported from the sweet potato stem borer (*Omphisa anastomosalis*), and from pupæ, a chalcid, probably belonging to the genus Hockeria, which has not previously been recorded in Hawaii.

The parasitism of all these species is apparently incidental and of rather small extent.

BEAN WEEVILS.

It has long been recognized that the value of the kiawe bean (*Prosopis juliflora*) as a stock food would be greatly increased if the pods were finely ground so as to put the seeds, which are rich in protein, in a digestible condition. With the perfection of machinery for this purpose, the losses occasioned by the bean weevils (bruchids), the larvæ of which largely feed upon the seed, again become a matter of importance. There are now two species of weevils attacking the kiawe bean, *Bruchus prosopis* and *Caryoborus gonagra*—both introduced pests. The work of the former has been known for a long time and the insect is common on all the islands. The latter species was first noticed in 1908 in Honolulu. Since then it has spread over the lowlands of Oahu and has also been found on the island of Kauai, so that there is no reason to doubt that ultimately it will have the same general distribution as the earlier species.

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[1] Hawaii Sta. Bul. 18.

The kiawe bean weevils are more or less familiar insects, but a short account of their life history will probably not be superfluous. The eggs are laid singly on the pods, one female weevil laying many eggs successively over the pod. The eggs are pearly, later turning creamy white, short oval, convex, microscopically reticulate, with distinct margin. There is no definite distinction between the eggs of the two species, and probably they can not be told apart. Those of *C. gonagra* are slightly larger. The egg (of *B. prosopis*) hatches in 10 days. The larva, which is stout bodied, yellowish white with black head, immediately burrows into the pod, often from beneath, so that the exposed portion of the egg is not broken. Making its way through the pulp, the grub finally reaches a seed, eats out its contents, and moves on to another seed—and so on until after 18 to 20 days it is full grown and pupates. After a variable period, usually 10 to 12 days, the pupa transforms into an adult beetle. The complete life cycle therefore covers about 40 days. The two species have been found working together in a single lot of beans. The larvæ of both beetles before pupating make an exit hole for the adult beetle, leaving only a thin film of cortical tissue to be eaten or broken through. These in the case of *C. gonagra* are much more conspicuous on account of their larger size and the thinness of the film. *C. gonagra* larvæ also make a cocoon within which to pupate and usually remain inside the cocoon for 3 to 4 days after becoming fully mature. The adults are easily distinguished, as *C. gonagra* is nearly twice the size of *B. prosopis* and is reddish brown, whereas the latter is more or less grayish marked with black.

An attempt was made several years ago to introduce from Texas certain hymenopterous parasites of the bean weevils, which, if established in Hawaii, would materially reduce the losses occasioned by these insects. Several consignments were received from the southern field laboratories of the Federal Bureau of Entomology, out of which one species (*Heterospilus prosopidis*?) bred by the thousands, and was liberated in several widely removed localities. While it is probably too early to state conclusively that this species has not become established, after three years it has not been recovered, although each year material has been especially bred for this purpose. In the material from Texas, however, was a minute hymenopterous parasite to which little importance was attached at the time the consignments were received, but which has now become established and proves a most valuable check to the multiplication of the weevils. This parasite, which attacks the eggs of the bean weevils, formed a new genus and species of Trichogramminæ and was recently described by

A. A. Girault as *Uscana semifumipennis*.[1] The parasite has already become rather generally distributed, and with the movement of beans from one locality to another will undoubtedly in time be spread over all the islands. The value of this check on the bean weevils will be realized from the results of an examination of a lot of beans recently, in which over 25 per cent of the eggs were parasitized.

SCALE INSECT PARASITES.

In connection with the study of the scale insects (Coccidæ), some attention has been given to the hymenopterous parasites of these and related insects, and an attempt has been made to bring together the records of parasitism in this economically important group, so that they will be available for reference to economic entomologists. This work was greatly facilitated by the loan of specimens in the collections of the Hawaiian Sugar Planters' Experiment Station and of the Board of Forestry and Agriculture, and the writer's thanks are due Mr. E. M. Ehrhorn and Dr. R. C. L. Perkins for many valuable records and suggestions in the elaboration of the material. Two new genera and three new species in the collections are herewith described. The lists which follow the descriptions are intended to present an orderly arrangement of the parasite species with their host relationships, and a table at the end shows the extent of the parasitism of the different species.

APENTELICUS gen. nov.

Near *Pentelicus* Howard, but at once distinguished from that genus by the insertion of the antennæ near the middle of the face. Body short, compact; abdomen small and triangular. Head transverse, lenticular, but not to the extreme degree seen in *Blepyrus*. Front fairly broad, with small thimble-like punctures, face wide, not retracted as in other genera, with rather broad longitudinal carina. Ocelli forming an obtuse triangle, the lateral members a trifle more than their diameter from the eye margin. Antennæ filiform, the broadly expanded scape short, not reaching ocelli; pedicle short, obconic, club not longer than the two preceding funicle joints. Punctuation of the thorax different from that of the head, very feeble. Marginal vein of wings short, less than twice as long as wide, postmarginal and stigmal veins rather short, subequal in length.

Type. The following species:

A. kotinskyi sp. n.

♂. Length of body, 1.17 mm., expanse of wings, 2.43 mm., greatest width of forewing, 0.47 mm. Head on vertex a brilliant metallic green with aeneous reflections, face and cheeks bluish green, eyes and occiput almost black. Ocelli reddish, mandibles brown, palpi yellow, antennæ sordid pale brown. Pronotum and mesonotum with axillæ metallic green, scutellum, mesopleuræ, and abdomen green with bluish reflections, legs pale brown. Body not especially stout, rather completely clothed with short white hairs. Thimble-like punctures on front of head extending on to vortex. Eyes small, widely separated. Antennæ 9-segmented (club undivided), long, filiform, extremely pilose, pedicle less than half the length of first funicle joint, funicle joints elongate, first more than twice as long as wide, club small, inconspicuous. Thorax scarcely convex, microscopically reticulate, feeble punctures of mesonotum arranged in more or less definite longitudinal rows, each puncture the point of insertion of a short white hair; scutellum shagreened with a few long hairs apically; mesopleuræ bare. Inner angles of the axillæ widely separated. Abdomen flat, short, acutely pointed at apex, with rather sparse vestiture of very short hairs and two lateral tufts of long hairs basally. Legs fairly stout, shortly and densely pilose. Wings hyaline, marginal vein short, postmarginal vein about as long as stigmal, which is fairly well developed.

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[1] Trans. Amer. Ent. Soc., 37 (1911), No. 1, p. 22.

Hab. Honolulu, Hawaiian Islands. Bred from *Lepidosaphes* sp.?

Adelencyrtus odonaspidis sp. n.

Length, 1.17 mm., wing expanse, 2.25 mm., greatest width of forewings, 0.33 mm. Metallic green, the face, genæ, prothorax, mesopleuræ, metathorax, and abdomen with purplish reflections. Head with face retracted below the eyes and lying in the dorsoventral plane, posteriorly widening to the genæ, which are also well developed. Eyes black, hemispherical, the inner margins almost parallel, but rather widely separated; scrobes semicircular, inner margins forming a well defined carina. Fronds sparsely punctate, bearing whitish hairs; ocelli red and arranged in a triangle, the lateral members close to eye margin. Antennæ brown, basal joint of club dark; 11-jointed, arising not far from mouth border, the scape clavate, reaching anterior margin of face, pedicle obconic, longer than the following four submoniliform funicle joints, two remaining joints of funicle larger, almost quadrate, club somewhat expanded and almost as long as funicle. Prothorax well developed and anteriorly conically produced. Mesonotum flat and with mesopleuræ microscopically reticulate, the former bearing regular longitudinal rows of black hairs. Axillæ narrow, indistinctly meeting at the middle and with the triangular scutellum, which is nearly as long as the mesonotum, shagreened. Metanotum and abdomen smooth, the latter dorsally rather flat, collapsing after death, apex produced to a point. Fore and mid legs pale brown, hind femora black except at base, the hind tibia basally with black annulus. Ovipositor slightly exserted, brown. Wings fuscous with a hyaline band just beyond stigma and an oblique hairless line extending inward from same. Veins black, marginal vein obscured by infuscation but quite long, stigmal vein very short and thick, postmarginal still shorter.

Distinguished from other species in the genus by infuscation of wings.

Hab. Honolulu, Hawaiian Islands. Described from several specimens bred from *Odonaspis graminis* and given by Ashmead the manuscript name of *Amicroterys kotinskyi.*

PTEROPTRICHOIDES gen. nov.

Belongs in the same category as *Pteroptrix* but antennal and wing characteristics are essentially different. Head slightly produced in front and excavated below eyes for insertion of antennæ; ocelli forming an obtuse triangle, the lateral members close to eye margin; antennæ 8-jointed, inserted below the middle of the face, scape long, only slightly swollen, pedicle obconic, less than one-third as long as scape, funicle joints wider than long, the middle one the smallest and only half as long as wide, the entire funicle only a little longer than the pedicle, club large, elongate, joints subequal and fluted, gradually narrowing to a point at apex. Thorax convex, pronotum inconspicuous, mesonotum and scutellum forming a broad carapace, mesoscutar parapsides wedge-shaped, posteriorly very narrow, and much pressed by the advancement of the almost quadrate axillæ. Abdomen short, completely sessile, rounded at apex, ovipositor with prominent, long, thin, flat valves slightly exserted, and extending upward almost to the level of the dorsum. Legs stout, all the tarsi 4-jointed. Forewings with long marginal fringe and sparse discal ciliation, the marginal vein almost as long as the submarginal, the tip reaching middle of wing. Hind wings narrow, with long marginal fringe and short discal cilia; marginal vein ending at middle of wing, which is there somewhat produced anteriorly.

Type. The following species:

P. perkinsi sp. n.

Length, 0.7 mm., expanse of wings, 1.34 mm., greatest width of forewings, 0.2 mm. Color in balsam dark brown, eyes black, ocelli red, legs pallid. Occiput finely aciculate, the aciculation extending on to vertex, which also bears a few sparse hairs. Forewings clouded basally to apex of the marginal vein, which is thick, ending at middle of wing. Stigmal vein entirely undeveloped.

Hab. Honolulu, Hawaiian Islands. Bred from a coccid (n. g. and n. sp.) on Bombay mango by Mr. Jacob Kotinsky, August 24, 1906.

List of parasites and their hosts.

CHALCIDOIDEA.

ENCYRTIDÆ.

Ectromini.

Parasites.	Hosts.
Anagyrus sp.?	*Pseudococcus* sp.

Encyrtini.

Encyrtus fuscus	*Saissetia hemispherica.*
Encyrtus sp. (with banded ant.)	*Saissetia* sp.
Encyrtus sp	*S. hemispherica.*
	Coccus viridis.

Mirini.

Blepyrus insularis	*Pseudococcus aonidum.*
	P. virgatus.
Aphycus sp.?	*P. calceolariæ.*
Aphycus sp.?	*Lepidosaphes* sp.
Microterys flavus	*Pulvinaria mammæ.*
	P. psidii.
	Ceroplastes rubens.
	Saissetia hemispherica.
	S. nigra.
Apentelicus kotinskyi	*Lepidosaphes* sp.
Adelencyrtus odonaspidis	*Odonaspis graminis.*
Cerapterocerus sp	*Saissetia hemispherica.*
	Aspidiotus sp.?
Hemencyrtus sp.?	*Saissetia nigra.*
Aphidencyrtus sp.?	*Aphis maidis.*
Encyrtus sp.?	*Pseudococcus citri.*

PTEROMALIDÆ.

EUNOTINÆ.

Scutellista cyanea	*Saissetia hemispherica.*

SPHEGIGASTERINÆ.

Tomocera californica	*Asterolecanium pustulans.*
	Saissetia hemispherica.
	S. nigra.
T. ceroplastis	*Ceroplastes rubens.*

EULOPHIDÆ.

ENTODONINÆ.

Astichus sp	?

APHELININÆ.

Aneristus ceroplastæ	*Ceroplastes rubens.*
Coccophagus orientalis	*Pseudococcus* sp.
	Coccus viridis.
Coccophagus lecanii	*Aspidiotus rapax.*
Encarsia sp	*Aleyrodes sonchi.*
Thysanus sp	*Asterolecanium pustulans.*
	Aspidiotus cydoniæ.
Aphelinus diaspidis	*Diaspis bromeliæ.*
	Aulacaspis rosæ.
	Hemichionaspis minor.
	Aspidiotus camelliæ.
Aphelinus sp. (wingless)	*Lepidosaphes* sp.
Pteroptrichoides perkinsi	Coccid (n. g., n. sp.) [Kot.].
Pteroptrichoides sp	*Asterolecanium pustulans.*
	Howardia biclavis.
Aspidiotiphagus citrinus	*Hemichionaspis minor.*
	Chrysomphalus aonidum.
Eretmocerus corni	*Aleyrodes hibisci.*

ICHNEUMONOIDEA.

BRACONIDÆ.

APHIDIINÆ.

Diaeretus rapæ	*Aphis brassicæ.*
	Macrosiphum sp.

CYNIPOIDEA.

FIGITIDÆ.

EUCOILINÆ.

Eucoila sp.?	*Macrosiphum* sp.
	Aphis sacchari.

List of hosts and their parasites.

COCCIDÆ.

DACTYLOPIINAE.

Hosts.	Parasites.
Asterolecanium pustulans	*Pteroptrichoides perkinsi.*
	Thysanus sp.
	Tomocera californica.
Pseudococcus aonidum	*Blepyrus insularis.*
P. calceolariæ	*Aphycus* sp.
P. citri	*Encyrtus* sp. (Mirine).
P. virgatus	*Blepyrus insularis.*
Pseudococcus sp	*Coccophagus orientalis.*
Pseudococcus sp	*Anagrus* sp.?

COCCINÆ.

Pulvinaria mammæ	*Microterys flavus.*
P. psidii	*M. flavus.*
Ceroplastes rubens	*Aneristus ceroplastæ.*
	Microterys flavus.
	Tomocera ceroplastis.
Coccus viridis	*Coccophagus orientalis.*
	Encyrtus sp.
Saissetia hemispherica	*Microterys flavus.*
	Tomocera californica.
	Scutellista cyanea.
	Cerapterocerus sp.?
	Encyrtus fuscus.
	Encyrtus sp.
Saissetia nigra	*Hemencyrtus*.?
	Microterys flavus.
	Tomocera californica.
Saissetia sp	*Encyrtus* sp. (with banded ant.).

DIASPINÆ.

Howardia biclavis	*Pteroptrichoides* sp.
Diaspis bromeliæ	*Aphelinus diaspidis.*
Aulacaspis rosæ	*A. diaspidis.*
Hemichionaspis minor	*A. diaspidis.*
	Aspidiotiphagus citrinus.
Aspidiotus excisus	?
A. camelliæ	*Aphelinus diaspidis.*
A. cydoniæ	*Thysanus* sp.
A. rapax	*Coccophagus lecanii.*
Aspidiotus sp	*Cerapterocerus* sp.
Chrysomphalus aonidum	*Aspidiotiphagus citrinus.*
Odonaspis graminis	*Adelencyrtus odonaspidis.*
Lepidosaphes beckii?	*Aphycus* sp.
Lepidosaphes sp	*Apentelicus kotinskyi.*
	Aphelinus (wingless).

ALEYRODIDÆ.

Aleyrodes hibisci	*Eretmocerus corni.*
A. sonchi	*Encarsia* sp.

APHIDIDÆ.

Macrosiphum sp	*Eucoila* sp.?
	Diæretus rapæ.
Aphis maidis	*Aphidencyrtus* sp.?
A. gossypii	*Aphelinus diaspidis.*
A. brassicæ	*Diæretus rapæ.*

The host relationship of scale insect parasites.

Parasites.	*Asterolecanium pustulans.*	*Pseudococcus aonidum.*	*P. calceolariæ.*	*P. citri.*	*P. virgatus.*	*Pseudococcus* sp.	*Pseudococcus* sp.	*Pulvinaria mammæ.*	*P. psidii.*	*Ceroplastes rubens.*	*Saissetia hemispherica.*	*S. nigra.*	*Saissetia* sp.	*Howardia biclavis.*	*Diaspis bromeliæ.*	*Aulacaspis rosæ.*	*Hemichionaspis minor.*	*Aspidiotus camelliæ.*	*A. cydoniæ.*	*A. rapax.*	*Aspidiotus* sp.	*Chrysomphalus aonidum.*	*Odonaspis graminis.*	*Lepidosaphes beckii.*	*Lepidosaphes* sp.	*Aphis maidis.*	*A. brassicæ.*	*Macrosiphum* sp.	*Aleyrodes sonchi.*	*A. hibisci.*
Anagyrus sp						×																								
Encyrtus fuscus											×																			
Encyrtus sp				×																										
Encyrtus sp											×																			
Encyrtus sp											×																			
Blepyrus insularis		×			×																									
Aphycus sp			×																											
Aphycus sp																									×					
Microterys flavus								×	×	×	×	×																		
Apentelicus kotinskyi																									×					
Adelencyrtus odonaspidis																							×							
Cerapterocerus sp											×										×									
Hemencyrtus sp												×																		
Aphidencyrtus sp																										×				
Scutellista cyanea											×																			
Tomocera californica	×										×	×																		
T. ceroplastis										×																				
Aneristus ceroplastæ										×																				
Coccophagus orientalis							×																							
C. lecanii																				×										
Encarsia sp																													×	
Thysanus sp	×																		×											
Aphelinus diaspidis															×	×	×	×												
Aphelinus (wingless)																									×					
Pteroptrichoides perkinsi	×													×																
Aspidiotiphagus citrinus																	×					×								
Eretmocerus corni																														×
Diaeretus rapæ																											×	×		
Eucoila sp																												×		

NOTES ON BREEDING AND IMMATURE STAGES OF COCCINELLIDÆ.

Some work has been done on the identification of the immature forms of the different species of coccinellid beetles, which have considerable interest as enemies of the scale insects, leaf hoppers, plant lice, white flies, etc. The life history of three species has been fully worked out, and the data, together with some miscellaneous notes on these insects, are here presented.

Coelophora inequalis.—This species, which was formerly known by the name of *Coccinella repanda,* has been shown by Dr. Perkins and others to be quite distinct from that species and is now definitely known to be the above. An account of its life history is presented by Swezey in a bulletin of the Hawaiian Sugar Planters' Station.[1]

Coelophora pupillata.—Eggs elongate oval, 1 mm. long, chrome yellow, laid on end on the surface of a leaf in clusters of 5 to 10 or more.

Larva when hatched, 2 mm. long, similar in shape to young larva of *C. inequalis.* Dusky black, white spot laterally on first abdominal segment and a transverse band of white on fourth abdominal

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[1] Hawaiian Sugar Planters' Sta., Div. Ent. Bul. 1, pt. 7, p. 228.

segment. A white line down center of thorax and abdomen to the band on fourth segment. Legs black.

Molts four times previous to pupation.

Full-grown larva shining black with the following markings: A thin line on anterior margin of prothorax and an inverted V-shaped wedge on posterior margin medially; on mesothorax laterally and an inverted V-shaped marking medially reaching anterior margin, same on metathorax, white; orange spot laterally on first abdominal segment and orange band on fourth abdominal segment; median and four lateral longitudinal lines traversing the entire abdomen, white, as also the hind margin of segments 7 and 8. Legs strong and conspicuous. Venter fuscous. 8.5 mm. long.

Pupa like that of *C. inequalis.*

	Days.
Egg stage	3 to 4
Larval stage	15 to 21
Pupal stage	7

Platyomus lividigaster.—The name Pseudoplatyomus is suggested for Platyomus, which is preoccupied in Rhyncophora.

Eggs elongate oval, very small, 0.75 by 0.35 mm., yellowish to brownish, laid in numbers (15 to 20 or more) on their sides on surface of leaf.

Larva when hatched 0.75 to 1.5 mm. long, yellowish brown, with a longitudinal row of fuscous tubercles on either side near margin. Legs fuscous.

Four molts previous to pupation.

Full-grown larva 5 mm. long, reddish brown with longitudinal rows of tubercles as in immature larva. Head fuscous, tubercles white at apex, fuscous at base and surrounded with black on meso- and metathorax and abdominal segments 5 to 9. Legs blackish. Waxy secretion ventrally on thorax and first four abdominal segments.

Pupa reddish yellow mixed with black. Length 3.5 mm., width 2.5 mm., depth 2 mm. Attached by posterior end. Ventrally flat, dorsally convex and carinated. A faint median and two more pronounced lateral longitudinal carinæ. Three conspicuous spines immediately in front of middle, almost entirely covered with white waxy secretion. In pupating the larva rotates its body around the point of attachment, at the same time depositing a thin film of white waxy secretion.

	Days.
Egg stage	3 to 4
Larval stage	7
Pupal stage	5 to 6

Scymnus notescens.—Eggs flat, 0.63 by 0.41 mm., oval or irregular in outline, slightly convex above, ochraceous, finely punctured. Many eggs laid singly on leaf or stem.

Larva when hatched 0.75 mm. long, elongate oval, rather flat, sordid white to greenish black, a black protuberance bearing two hairs laterally on each segment, forming a marginal fringe. Head black, truncate, two large black bars on first thoracic segment, remaining thoracic segments white. Indistinct dark spots and dark line to fourth abdominal segment. Whitish capitate hairs in longitudinal lines on dorsum, four on either side.

Full grown larva 3.5 mm. long, nearly 2 mm. wide, long oval, only slightly convex, head small, labelliform and retractile, prothorax distinctly constricted from the rest of the body, flat above and carapace-like, subquadrate, anteriorly and laterally, with a fringe of very fine hairs. Segments of body rather indistinctly marked, a lateral protuberance on meso- and metathorax and abdominal segments 1 to 8, forming a fringe, each protuberance bearing fine white setæ. Anal segment with caudal fringe of fine white hairs, fine hairs on each side. A transverse line of small white setæ and many scattered hairs on each segment behind head. Color yellowish brown, with a median and two lateral lines fuscous to dark brown, the head and legs outwardly also fuscous to dark brown, basally yellowish, a pale yellow spot on mesothorax and one on anterior margin of metathorax, the prothoracic shield with a median light line separating darker areas, pale again on lateral margin. Lateral protuberances almost black, ultimate segment with median black spot. Venter yellowish brown.

Pupa oval, more or less truncate anteriorly and posteriorly and quite convex. Attached caudally. Head beneath prothoracic carapace forming anterior end of body, wing covers reaching beyond second abdominal segment, laterally to fourth abdominal segment, tips reaching posterior margin. Body covered with whitish hairs. A median longitudinal carina on abdomen dorsally brownish, the prothoracic carapace and last abdominal segment blackish, a median light yellow line on metathorax and abdominal segments. Legs black.

	Days.
Egg stage	1 to 2
Larval stage	10
Pupal stage	5

MEDITERRANEAN FRUIT FLY.

The predictions made in regard to the harmful nature of this fly have been fully justified by the experience of the past year. With optimum conditions for its development and practically no natural checks, the fly has increased with astonishing rapidity, and with the clandestine movement of fruit from one island to another, has spread to and become firmly established in all the principal islands of the group. The fly has shown a wide range of adaptability to different kinds of fruits, and from the six or seven fruits mentioned in the last annual report as attacked by this pest the list of infested fruits has swollen to the extent of including nearly every fruit with soft pulp in the islands. With many of these fruits, however, the infestation is largely incidental, and there is an undoubted preference shown for peaches, coffee berries, citrus fruits, and kamani seeds.

Little has been actually accomplished in the way of controlling the fly and little can be done under the peculiar conditions existing here, with large areas of uncultivated land and forest supporting a wild growth of fruit-bearing trees, shrubs, and herbs in which the fly can maintain itself in spite of all efforts at artificial control. In circumscribed areas, where the protection of valuable edible fruits made it seem desirable to attempt its control, the commonly recognized methods, such as destruction of infested fruit, spraying, or poisoned bait, and trapping with kerosene, have been tried with fair success. By these methods the fly is reduced to a minimum during the winter months, but with the approach of summer and the appearance of the heavy fruit crops the expense of an adequate control becomes almost prohibitive and the work is surrounded by many almost insurmountable difficulties.

The spread of the fly to the Kona coffee fields for a time produced alarm, but it has not yet been demonstrated that the fly affects the coffee bean in any way or causes any great loss in connection with the crop. The dropping of immature berries, which has been partly ascribed to the fly, is a usual occurrence and may be due to several causes. The fly's part in it is obscured by the phenomenally large crop of the present year.

MISCELLANEOUS WORK.

Some attention has been given to beekeeping and certain aspects of the industry are being carefully studied. During the year two papers on insects have been prepared for publication, one on the insects attacking the avocado in Hawaii, the other on the insects attacking the pineapple.

REPORT OF THE HORTICULTURIST.

By J. EDGAR HIGGINS.

The work of the horticultural department has proceeded along about the same lines as were indicated in the last annual report. The subjects which have received chief attention have been the avocado, the mango, the pineapple, and the papaya. Quite a number of noteworthy varieties of hibiscus have been originated by Mr. Valentine S. Holt, assistant in horticulture. Some attention has also been given to a number of miscellaneous subjects, as the treatment of bananas for shipping, a special method for pruning the peach in this climate, a brief survey of some of the results of onion growing on Kauai, together with assistance rendered at the Homestead substation on Kauai.

In addition to these lines of experiment and investigation, there has been a much larger amount than usual of construction work in progress. Under the immediate supervision of Mr. C. J. Hunn, assistant horticulturist, there have been erected a new insect-proof glass house, a shade house and potting shed, and a workshop and storeroom for horticultural purposes is just being completed. These buildings, together with several new insect-proof tables, add greatly to the equipment.

THE PINEAPPLE.

The most important present horticultural pursuit in Hawaii is pineapple growing. This industry has grown in a little more than a decade from an insignificant position in the activities of the Territory to a place second only to sugar production. The pack of canned pineapples for the present season is estimated at about 1,000,000 cases, valued at $3,000,000. The Hawaiian pineapple has gained a reputation in American markets in the form of fresh fruit and in the can. The canned product has found even a wider field and is being shipped to Europe and other foreign countries. The large demand has stimulated further plantings, and new companies or those already in the business have acquired leases during the year on several thousand acres of land not heretofore under cultivation. The Territorial government has opened for homesteading several tracts of land supposed to be well adapted to the pineapple, and these also will probably be planted chiefly to this crop. Indeed, it seems not improbable that the present output may be again doubled in the next few years.

How long the demand will keep ahead of the supply and to what extent the Hawaiian trade will be affected by the increasing output of Porto Rico, Cuba, or the Philippines are problems which some of the growers are studying. At present there is no slackening in the demand.

This extension of the pineapple area in Hawaii, and in particular on homestead lands, has given rise to a demand for information relative to the growing of the crop. This station has published from time to time several bulletins on specific phases of the subject, including problems connected with soils, insect pests, diseases, and the marketing of the fresh fruit. Nevertheless, many phases of the subject concerning which inquiry is frequently being made had not been touched upon in these publications, and an attempt has been made to meet this demand in part by a general bulletin from the horticultural division of the station on "The Pineapple in Hawaii." This bulletin[1] includes the results of a few recent investigations as well as a general statement of methods in practice in pineapple growing.

THE AVOCADO.

PROPAGATION.

The experimental work in the propagation of the avocado during the year has been concerned chiefly with the use of quite young seedlings. These have been used both as budding stock and for inarching. (Pl. II, fig. 2, B and C.)

For budding, the stocks have been grown either in nursery row or in containers, such as soy tubs, shingle boxes, ordinary earthen pots, and tin cans. The seeds may be germinated in these or in "ti" leaf pots.[2] Soy tubs from which the salt has been thoroughly washed are satisfactory for a few plants, particularly if they are to remain for some time without transplanting, but the tubs are entirely too large to be economical of space, soil, or transportation costs. They can be bought in quantity for 10 to 12 cents each. Boxes 6 to 8 inches square and about 10 inches high can be made of shingles at a cost of approximately 10 cents each, and these are large enough to carry the plants through until the buds are well established. An ordinary earthen flowerpot serves the purpose well but is more expensive, and if the plant is removed from it and packed for shipping there is greater danger of injury than in the case of a young tree in the container in which it has been grown. One-gallon round tin cans appear to be quite satisfactory. There are usually many of

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[1] Hawaii Sta. Press Bul. 36.

[2] Hawaii Sta. Bul. 25, p. 13.

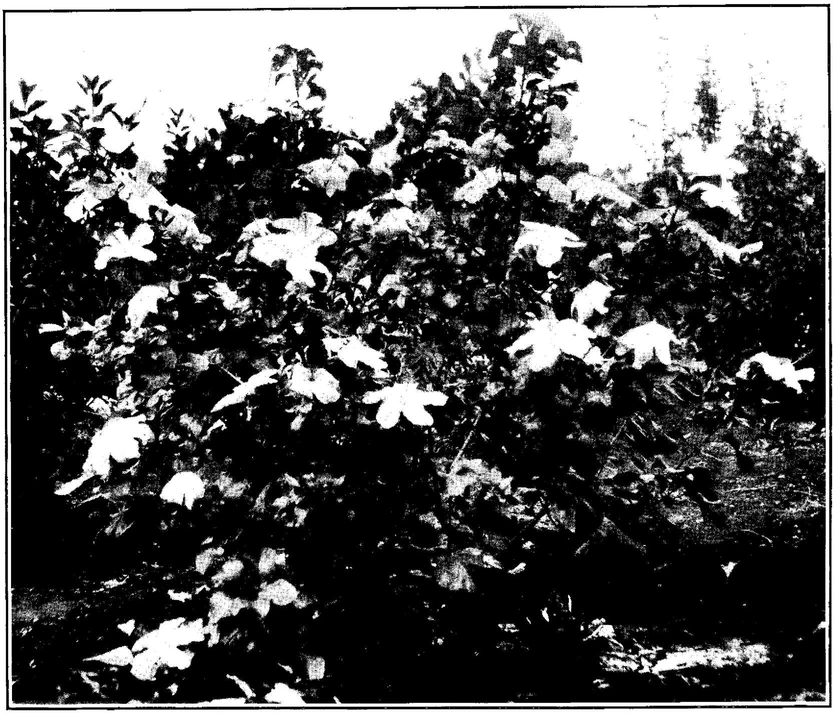

FIG. 1.—HIBISCUS, VARIETY RUTH WILCOX.

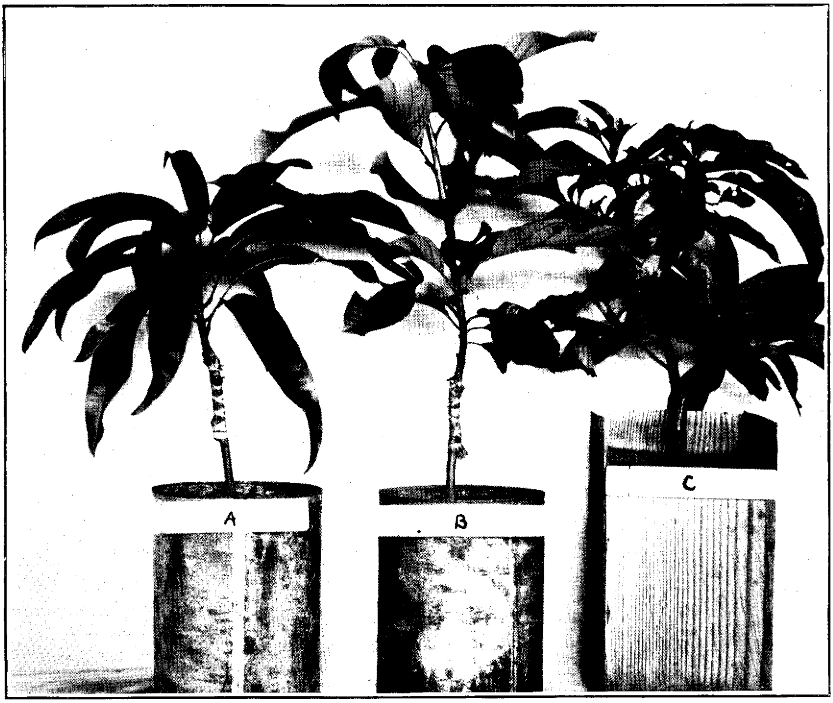

FIG. 2.—A YOUNG SEEDLING MANGO INARCHED; B, YOUNG SEEDLING AVOCADO INARCHED; C, YOUNG SEEDLING AVOCADO BUDDED.

these, more or less defective or damaged, that have been discarded at the pineapple canneries. If a cut is made with a can opener, nearly encircling the bottom, drainage is provided and the tree can be shipped in the can. Even when transplanting it is not necessary to take it out, since the bottom of the can may be bent back, affording an opportunity for the roots to get out. It is, however, an easy matter to cut the can on one side when the tree is in place and plant it without disturbing the root system in any way.

If placed in the nursery, the young plants should be about 18 inches apart in rows wide enough to permit of such implements of tillage as it is intended to use. Whether in pots or in the nursery, it is necessary to keep the seedlings in a healthy, rapidly growing condition. They may be budded when they are about five-sixteenths of an inch in diameter and will be ready for planting in garden or orchard in about a year from the germination of the seed.

Another means of shortening the time required in propagation has been the inarching of very young seedlings. For this purpose the seedlings are cared for in the usual way and when about five-sixteenths of an inch in diameter are transplanted to pots or boxes, placing the stem to one side rather than in the center so as to facilitate getting it into contact with the scion. A very convenient substitute for a pot has been suggested by Oliver.[1] This consists of a burlap wrapping. Burlap is cut in strips of suitable size to hold the plants and on this is placed a mixture of soil, sand, and sphagnum moss. The ball of soil surrounding the roots is placed upon this and the whole is wrapped and tied. The advantages of this device are that it is light, compact, and less clumsy than a pot and if necessary can be tied to a branch of the tree, thus eliminating the benches required to support pots. But even if the bench is used, as sometimes seems desirable, a great many more plants can be placed upon it in wrappings than in pots.

The inarching process for these very young seedlings is precisely the same as that for older plants and need not be further described here. It has been found advantageous to fertilize the seedlings about once in two weeks by the use of a small amount of fertilizer added to the water. In the case of avocados a union is effected in about six weeks.

Thus the avocado, which a few years ago was thought to be difficult or almost impossible of asexual propagation, is yielding to many methods of multiplication.

DISTRIBUTION.

By means of these experiments the station has at the same time been perpetuating a number of valuable varieties, some of which have been represented by a single specimen only and otherwise likely to become extinct. As there is no nursery in Hawaii where grafted or budded avocados can be secured, these plants are being distributed, a small charge being made for them.

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[1] U. S. Dept. Agr., Bur. Plant Indus. Bul. 202, p. 16.

One of the varieties which are now being sent out is of seedling origin and of the Guatemala type. It has been grown at the station and is worthy of being named, described, and distributed. This variety, which has been named the Nutmeg, is superior in some respects to its parent and has been described by Mr. C. J. Hunn, as follows:

> The Nutmeg avocado. Fruit from the original avocado tree of the Guatemala or "hardshelled" type [1] was collected in December, 1907. A seedling grown from this seed was placed in the orchard on March 17, 1908. This tree came into bearing in December, 1911, four years from seed.
>
> Form roundish to spherical, size medium; cavity small, shallow, and flaring; stem short and inclined to be thick; surface undulating, very hard; coriaceous and markedly pitted; color greenish purple to black with very abundant, irregular-shaped yellowish dots; apex a mere dot, slightly depressed; skin very thick and woody, separating fairly well from the pulp; flesh yellow in color, running into green at the skin; fine-grained, a trifle juicy, oily and somewhat buttery, 68 per cent of the fruit; seed large, roundish, flattened at the base, fitting tightly in the cavity; flavor rich and nutty. Season late.
>
> This tree is quite vigorous and is pyramidal in shape. Height 15 feet, spread 8 feet. (Hunn.)

DISEASES AND INSECTS.

A new injury resulting from the fungus Glœosporium [2] has been observed. A number of the seedling inarches referred to above were found dying back from the wound made in cutting off the scion or the top of the stock. In the case of the budded seeedlings a similar decay was found, beginning at the wound where the stock was headed back and extending down so low as to cut off the supply of sap from the growing bud. It was suspected that these injuries were due to the fungus just mentioned and specimens were submitted to Mr. L. D. Larsen, of the Hawaiian Sugar Planters' Experiment Station, who reported the fungus present in each case examined. It has not been determined whether the infection is frequently made with the knife or merely results from exposure to the spores carried by the wind. In any case it seems best to protect the wounds with grafting wax or with some antiseptic covering. If it should appear that the knife is a potent factor in carrying the disease it may be best to disinfect the blade when using suspicious bud wood.

The wood-boring beetle, *Xyleborus immaturus*,[2] made its appearance in the station orchard during the year and has been much complained of in other parts of the city. This has been combated at the station by pruning and by the use of a wash composed of 1 gallon soft soap, 3 gallons water, and ½ pint crude carbolic acid. This was applied to the trunks and branches of all the trees with a whitewash brush. The treatment appears to have held the insects in check.

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[1] Hawaii Sta. Rpt. 1910, p. 28, No. 149; Bul. 25, p. 43.

[2] Hawaii Sta. Bul. 25, p. 23.

THE MANGO.

The grafting of very young seedlings of the mango has been tested along the same lines as practiced with the avocado and with equally good results. (Pl. II, fig. 2, A.) The mangoes are better to be a little older than the avocado because they do not so quickly acquire the desired diameter of stem and because most of the shoots of the mango trees which are to be used as scions are of considerable size. It has also been found necessary to allow the mango inarches eight or nine weeks to unite, this being at least two weeks longer than the avocado requires. The mangoes that have been thus propagated are chiefly of the Indian and other varieties introduced in recent years but include also some choice kinds that have originated here.

Distributions of these grafted mangoes are being made as indicated for the avocado. The varieties being thus distributed are as follows: Alphonse, Pirie, Oahu, and Smith.

Some interesting results are now available showing the time required for the bearing of budded mangoes. An old tree partly top-worked to the variety Pirie, in February, 1910, is bearing this year some fruit which will mature in about two and one-half years from budding. The varieties Smith and Java are requiring about two and one-fourth years and the Gay a little more than three years. The latter, however, was budded very late in the season (May 24) and did not have the advantage of the best season of growth, which is from December to May. These results would suggest that trees budded in December or January may be expected to produce some fruit in about two years from the following June and July, these months being the mango fruiting season.

There are fruiting at the station this summer, but not mature enough for describing at the date of this writing, the following varieties: Brindabani, Totafari, Gay, Java, Wootten, Bennett Alphonse, Alphonse, Divine, Pirie, and Smith.

The mango is being very seriously attacked by the Mediterranean fruit fly, *Ceratitis capitata*, and it has been necessary to cover with cotton bags the fruits of many of the varieties. Although several fruits can be placed within one bag, the practice is tedious and expensive. Nevertheless, it is well worth the trouble in the case of the best varieties. Fortunately, not all varieties are equally susceptible, some being quite resistant. It can not be stated that there are any which are immune from the attacks of this fly, but no infestation has yet been found on the Brindabani, although the fruits are not ripe at this time and may be attacked later. The Smith and several of the Cambodiana type, locally known as "Chutney" varieties, appear to be attacked only slightly, and chiefly when the fruit is very ripe. By picking the mangoes of these kinds before they have begun to soften the fly can be avoided to a considerable degree. Too much confidence should not be placed in these habits, for there are many other varieties upon which the maggots may feed, and if these were not in fruit the flies might deposit more eggs in the fruits which now show resistant qualities.

THE PAPAYA.

The papaya investigations have been continued along the lines indicated in the last two annual reports. There is little to report in the way of new conclusions, but some interesting data are developing. One of the questions which have naturally arisen in this study has been whether the monœcious or the diœcious type is the more primitive, and, further, as to the origin of the later type. There are now under observation a series of gradations between the two types which appear to indicate that the monœcious papaya has developed from the staminate tree of the diœcious type. It was stated in earlier reports that this staminate tree occasionally produces a perfect flower which matures a fruit.[1] There are now trees at this station bearing none, others bearing only a few, and still others producing no less fruits than many pistillate trees. One has 87 fruits upon it at this writing. These fruits and the flowers that produce them are of the general form of the monœcious type. If, then, the long peduncle upon which they are born be shortened, the result would be the ordinary monœcious papaya. A tree has been under observation in which these peduncles are midway in length between those of the monœcious tree and those of the so-called "staminate" tree which produces fruit. The observer might be in doubt whether to call this tree one of the monœcious type with extra long peduncles or a "staminate" tree producing an extraordinary number of fruits, for these differ apparently only in the number of the fruits and the length of the peduncles. There is also under observation a staminate tree with flower stems as short as those of any pistillate tree. Some of the gradations referred to are illustrated in Plates III and IV.

But even if this series of gradations approaches completeness sufficiently to justify the conclusion that there has been an evolution from the one type to the other, the further question arises, Are we justified in concluding that the process has been in the direction sug-

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[1] All staminate flowers of these trees have aborted pistils, but, with the exceptions mentioned, they do not possess a stigma, and can not produce fruit.

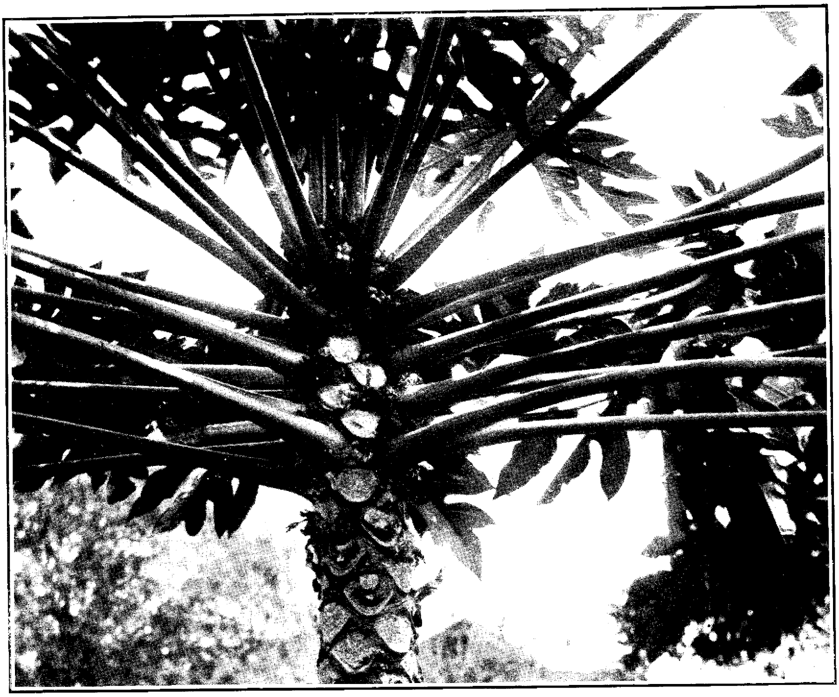

Fig. 1.—A Staminate Papaya Tree with Very Short Flower Stems.

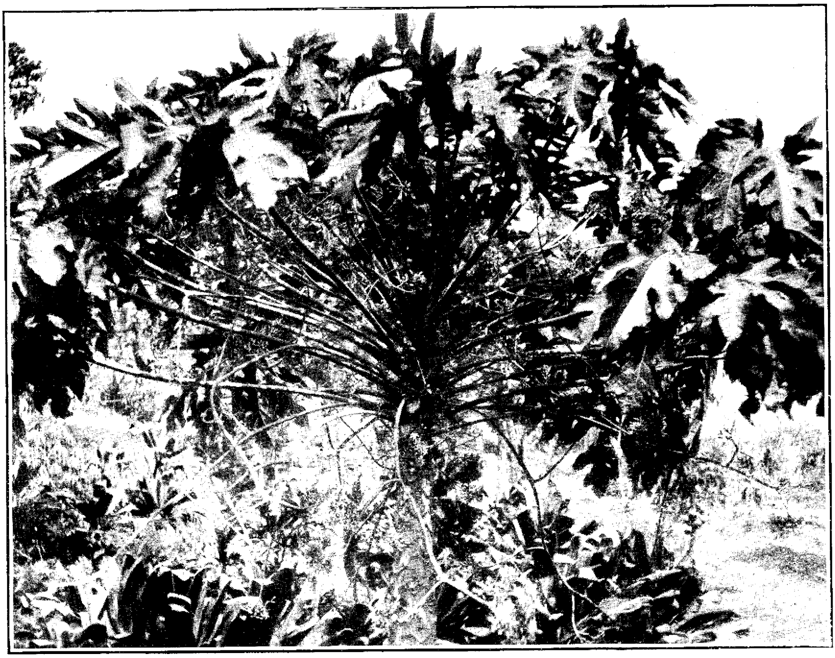

Fig. 2.—A Staminate Papaya Tree Bearing no Fruits.

PLATE IV.

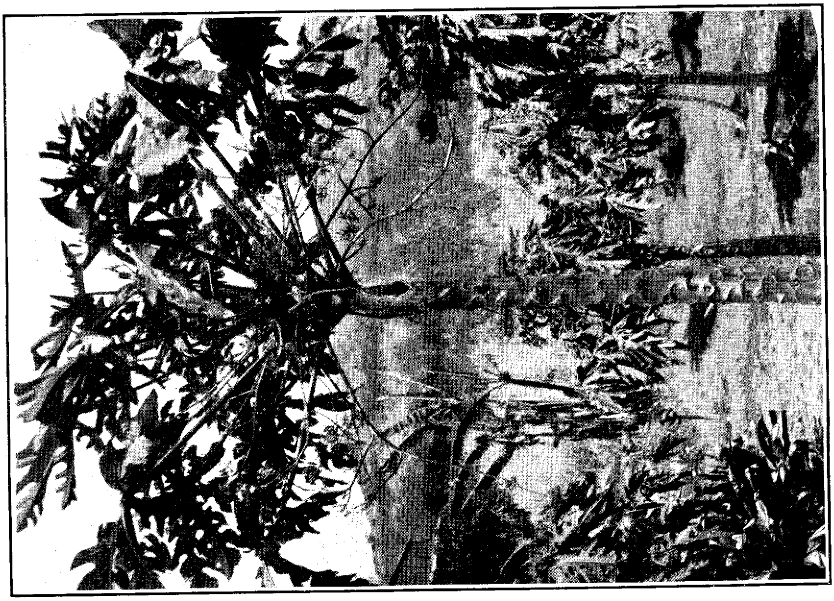

FIG. 1.—STAMINATE PAPAYA TREE BEARING ONLY TWO OR THREE FRUITS.

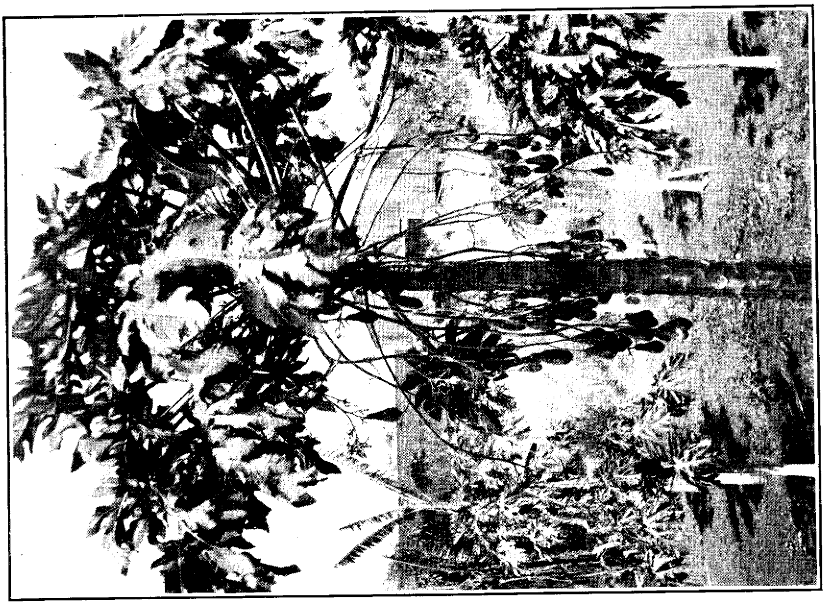

FIG. 2.—STAMINATE PAPAYA TREE BEARING MANY FRUITS.

gested and not the reverse—viz, from monœcious to diœcious? Proceeding temporarily upon the supposition that the monœcious type was the earlier form, it may be imagined that the peduncles became lengthened and the number of staminate flowers increased and the perfect flowers decreased until the evolution had arrived at a regular nonfruit-bearing staminate tree. But this would not account for the pistillate tree, which is the necessary counterpart of the staminate. To account for this, supposing the evolution to have proceeded in the direction hypothecated, it would be necessary that a pistillate flower of entirely new form be evolved from the perfect flower. All of this appears less probable than the suggestion that the diœcious type was the more primitive and gave rise to the monœcious.

In this connection it may be well to record a recent experience in planting. Papaya seeds were received from the United States Department of Agriculture, Office of Seed and Plant Introduction,[1] and planted under our accession number 1996. Sixty seedlings were set out in orchard form. Of these, 33 proved to be pure pistillate trees and 27 were staminate, a few of the latter producing an occasional fruit. One of these fruits was selected and its seeds planted. Of these, 16 trees were planted, and 4 of these are normal pistillate and 12 are staminate. But of the staminate trees 9 are bearing fruit and some of them in large numbers, such as 21, 37, and 87 fruits per tree. This may have some bearing upon the question which has been under discussion. In any event, the facts are of sufficient interest to record.

The work of breeding toward a reasonably stable variety of desired characters by means of cross pollination, close pollination, and selection is being carried on, and some excellent trees are being studied.

BANANA SHIPPING.

The shipping of bananas from Hawaii to the mainland has undergone some changes during the year. The spreading of the Mediterranean fruit fly in different islands of the group has led to increasing vigilance and greater caution on the part of California. It was thought that the banana leaves, in which the fruit has always been wrapped, were not a very safe packing. It was therefore directed by the California authorities that banana leaves must not be used, but that rice straw would be an acceptable material for the purpose. After a few shipments it was learned that the rice straw injured the rind of the fruit, causing it to become black. Then followed the testing of a paper wrapping inside of the rice straw and also of a cheesecloth wrapping. Each of these is reported to have afforded considerable protection, and one or the other is now in general use. Scale insects and mealy bugs of several species have also made it necessary to guard carefully incoming bananas at San Francisco. Because of these various difficulties some experiments were made in fumigating bananas with hydrocyanic-acid gas. Six bunches of bananas were secured on March 23 and held in the fruit room until March 29. Two bunches were then treated with 1½ ounces cyanid in 260 cubic feet for 45 minutes. Two others were given 2 ounces of cyanid for 45 minutes, and the remaining two were held as a check without treatment. The wrapping had been removed from all before treatment. Repeated examination of all these daily until ripe revealed no indication of any injury to the fumigated fruits.

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[1] S. P. I. No. 23915.

Again on April 3 a plantation was visited and six bunches were selected which were infested with the following scale insects and mealy bugs: Florida red scale (*Chrysomphalus aonidum*), the whitewash scale (*Hemichionaspis minor*), and a mealy bug (*Pseudococcus* sp.). These bunches were wrapped at once in banana leaves and taken to the experiment station, where they were held for two days. They were labeled 7, 8, 9, 10, 11, and 12, and treated on April 5 as indicated below:

No. 7. Not wrapped, not fumigated (check).

No. 8. Wrapped, not fumigated (check).

No. 9. Not wrapped, 1½ ounces cyanid in 260 cubic feet for 45 minutes.

No. 10. Wrapped, 1½ ounces cyanid in 260 cubic feet for 45 minutes.

No. 11. Not wrapped, 2½ ounces cyanid in 260 cubic feet for 60 minutes.

No. 12. Wrapped, 2½ ounces cyanid in 260 cubic feet for 60 minutes.

The fruits were carefully examined by the station entomologist after treatment, but in no case was a living insect found upon the fumigated bunches whether bare or within the wrapping. All were kept until fully ripe, which in the case of some bunches was over three weeks, and during this time careful observations were made by several members of the staff to discover any injury that might have been done to the fruit in fumigating. No difference could be detected between the fumigated and unfumigated fruit in appearance, texture, or flavor. It has been reported that injury has resulted from the treatment of bananas with this gas in San Francisco. It seems not improbable that this may have been the case, for bananas coming from a ship after a six-day voyage are liable to be moist, and it is a well-known fact that hydrocyanic-acid gas is injurious to tender plant tissues when they are wet. But from the experiments recorded above it is reasonable to conclude that if fumigation is necessary it may be practiced here before shipping without injury to the fruit and with deadly effect upon the insects.

HIBISCUS.

The hibiscus is now receiving much public interest and more requests have been received for cuttings of these plants than for any other. Over 25,000 cuttings have been distributed. Mr. Holt, who has charge of the hibiscus work, states that he now has over 200 new varieties under observation. Some of these are of great beauty and will add much to the floral wealth not only of Hawaii but of other parts of the Tropics and Subtropics. One of the most attractive of the new sorts is shown in Plate II, fig. 1. Mr. Holt has named this the Ruth Wilcox. A half tone can not do justice to such a flower, but reveals the free-flowering habit and good form of shrub. This is one of the few hibiscuses which emit a delicate perfume.

CITRUS.

The orchards of citrus which have been budded to many varieties are now coming into bearing. In the report of the assistant horticulturist will be found a list of the varieties which are fruiting.[1]

Bud wood of a number of these varieties has been distributed to various parts of the Territory and about 320 stocks in the station nurseries have been budded to some of the most promising.

The records of two trees budded to Kusaie lime in May, 1908, are worthy of note. They began fruiting in the fall of 1909 and have been in bearing almost constantly since that time. A record was kept of the yields in 1911, showing 467 fruits weighing 40½ pounds from one of these trees and from the other 419 fruits weighing 39½ pounds.

MISCELLANEOUS EXPERIMENTS AND OBSERVATIONS.

The horticulturist made a short trip to the island of Kauai in September to render some assistance to the Homestead substation and arrange for some trials in onion growing. Seeds of a large number of varieties of onions including some of the Bermuda type were later sent to Kauai and were planted at the substation at Homestead and in several other parts of the island.

At that time it had been rumored that the Mediterranean fruit fly had appeared at Makaweli. A brief investigation proved this to be the case and on August 28, immediately after the adult insects had been bred from the material collected on Kauai, the information was communicated to the Commissioner of Agriculture and Forestry. In May another visit was made to Kauai to review the onion tests mentioned above, to give some instructions in propagation at the substation, and to study the pineapple industry on that island. The last two subjects have been noted earlier in this report or in a press bulletin of the station on The Pineapple in Hawaii[1] and need not be further reported upon here. Some mention should be made of the results of the onion tests. The marketing division of the Territorial government had also distributed some very good seeds of the Bermuda type. Onions were found growing in many places from Waimea to Hanalei and in soils varying from heavy clay to light coral sand mixed with a small amount of humus. In general it may be stated that first-class marketable onions were found in many soils and at elevations ranging from sea level to 600 or 700 feet, which appeared to be about as high as they had been tried. On all the heavier soils, however, a serious disease was prevalent which appeared to be identical with the bacterial disease of this crop known as "center rot" or "slippery onions."[2] This disease may attack the top of the bulb and progress into the center, giving rise to the first of the names applied to it, or it may affect the outer scales causing them to decay and the onion to be very slippery, which has given rise to the second of the common names. The malady is one which prevails chiefly in heavy soils and in damp climates. Very little of it was found on the low sandy soils of Kauai, lying near the beach and supplied with moisture chiefly from beneath. In several places it was found that free water exists only a few feet below the surface of the soil and is conducted to the plants by capillarity. There is a considerable area of sandy and loamy soil on Kauai which appears to be adaptable to this crop, but as there is no effective remedy for the bacterial disease referred to, cultivation on the heavier soils should not be attempted without caution.

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[1] See page 48.

In closing it is desired to express appreciation of the very faithful services of Mr. C. J. Hunn, assistant horticulturist, and of Mr. Valentine S. Holt, assistant in horticulture.

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[1] Hawaii Sta. Press Bul. 36.

[2] New York State Sta. Bul. 164; Georgia Sta. Rpt. 1900, p. 355.

PLATE V.

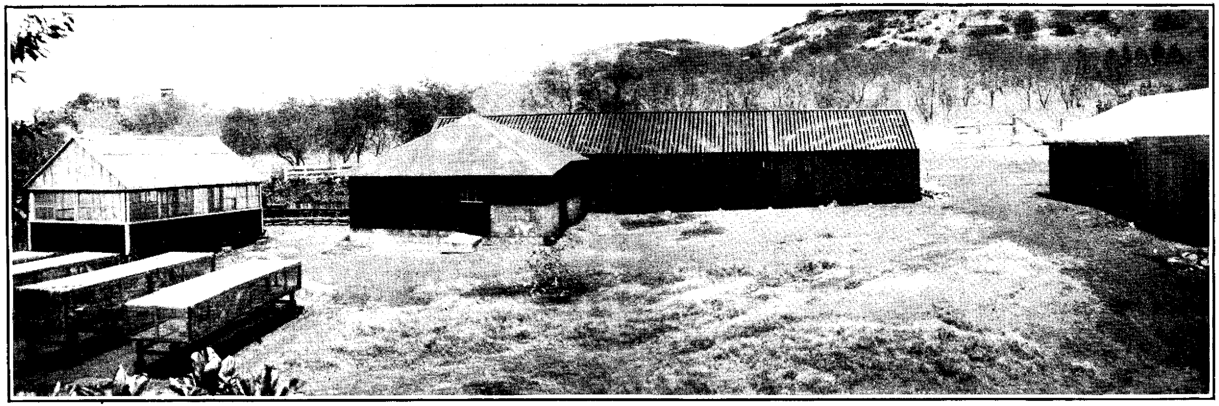

FIG. 1.—PANORAMA OF BUILDINGS.

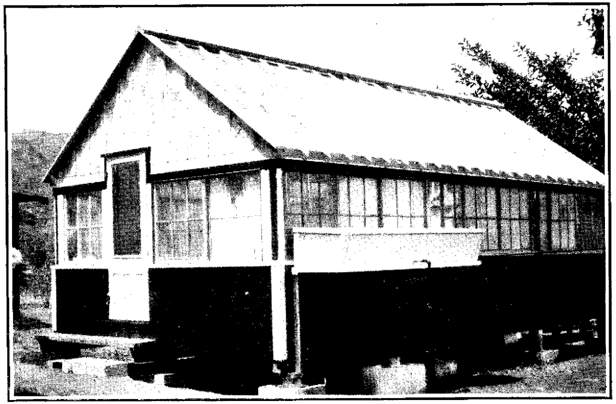

FIG. 2.—GLASS HOUSE.

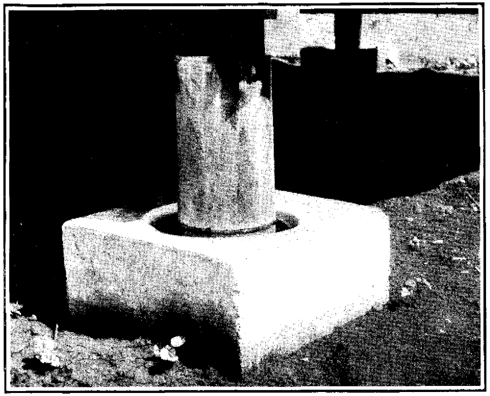

FIG. 3.—CEMENT PIER.

GENERAL VIEW OF HORTICULTURAL BUILDINGS.

REPORT OF THE ASSISTANT HORTICULTURIST.

By Chester J. Hunn.

BUILDINGS.

The year has been essentially one of reconstruction and building up. While passing through the transitional period between the discarding of the old and the actual construction of the new buildings (Plate V) six outside ant-proof benches [1] were erected.

A shade house supported by concrete pillars was the first building constructed. The slats in the old shade house showed a tendency to warp in all directions and to throw into the house the water that should be drained away. The adaptability of two grooves, one on either side and three-quarters of an inch from the edge of the upper surface of the slat, is now being tested. The opinion is that when the slats warp they will turn upward and form a trough which will insure better drainage.

Adjoining the shade houses is a potting room. It has a rock floor covered with a sloping concrete surface. In this room are a spacious potting bench, reinforced concrete bins for soil and sand, pot racks, and a packing table.

The necessity of a glass house for propagating purposes has been very apparent. It should be proof against insects, birds, and rodents, for the former shade houses were faulty in this respect. The regulation of temperature and air currents has also not been within the control of the propagator.

A glass house which should fulfill these conditions is practically finished, detailed plans of which are given herewith (fig. 1). All the supports and the piping are ant proof. Wooden doors near the floor, sliding glass sash on the sides, and ventilators in the roof control the ventilation of the house. All openings are covered with bronze mosquito wire. The intensity of the sun's rays will be regulated by whitewashing the glass and by the use of curtains.

The interior arrangement of the house affords means for several methods of plant propagation. The center bench is zinc lined for subirrigation purposes, especially for delicate seeds which do not permit of surface watering. At one end is a glass box for seeds requiring a high temperature in which the amount of humidity can be controlled.

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[1] Hawaii Sta. Rpt. 1911, p. 42.

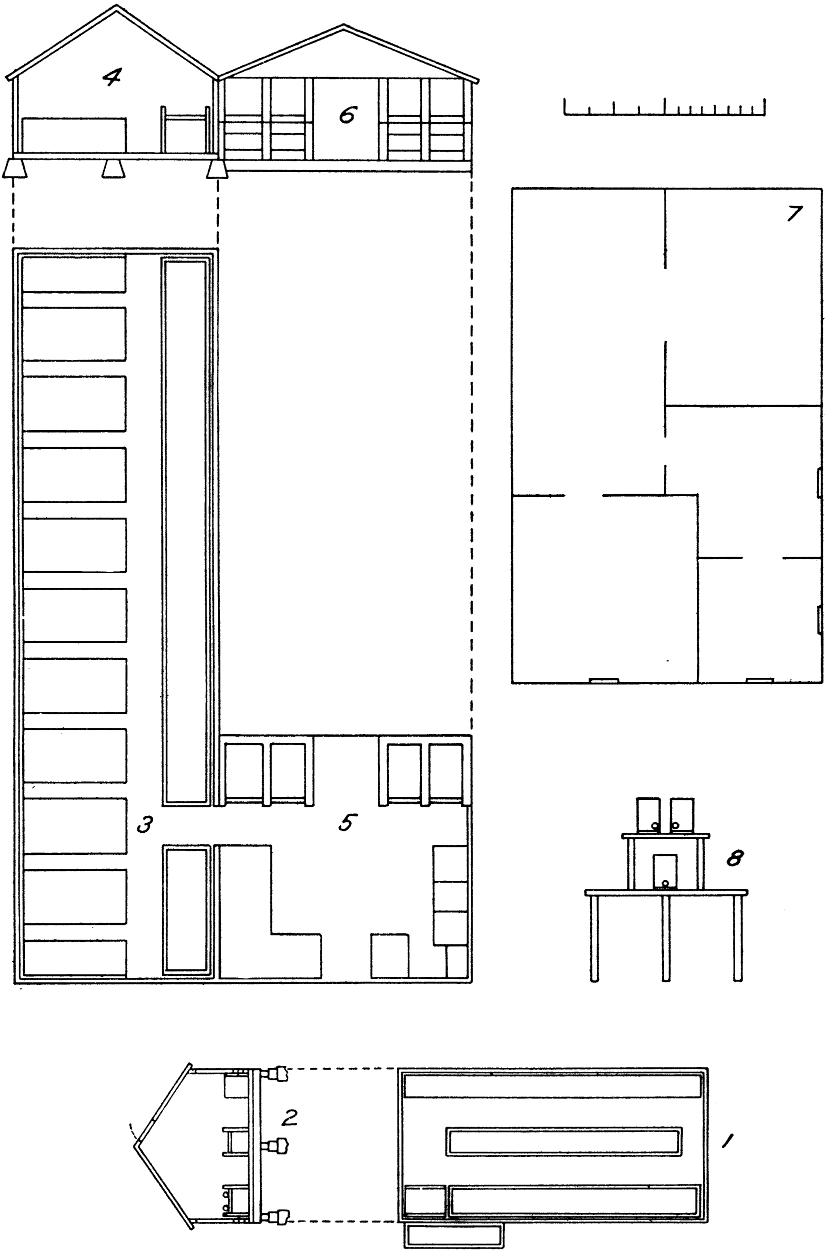

FIG. 1.—Details of horticultural buildings: 1 and 2, interior bench and elevation plans of glass house; 3 and 4, same of shade house; 5 and 6, same of potting house; 7, interior plan of work house; 8, elevation plan of spray stand. (Scale 16 feet to 1 inch.)

Experience in propagation by cuttings in the Tropics leads to the belief that bottom heat is necessary to the best success. Temperature readings in a thickness of 6 inches of moist sand show that the surface temperature is 6° higher than the bottom temperature. Cuttings should callus and root before the leaves reach a large size, in order to provide a portion of the sustenance for the leaves and to prevent them from using much of the material stored in the tissues of the cuttings. Under prevailing conditions the leaves uniformly appear before the root system has become well established.

Facilities are now at hand for practical work in the bottom-heating problem. Water, heated by the sun's rays in a glass-covered wooden box, is conveyed by pipe through the sand propagating bed. After the heat is dissipated the water is returned to the heater to complete the circulation.

This department has outgrown other appointments. This is being remedied by the construction of a work building divided into a poison room, rat and insect proof seed and fruit rooms, a storage room, and an open work compartment. A modern spray stand has been erected so that all liquids can be conveyed by gravity from the stock solution barrels to the mixing barrel and from hence to the spray barrel on a wagon. A reinforced concrete stove was also constructed. This stove affords a place for the cooking of spray mixtures, the boiling of fruit infested with fruit-fly eggs, and the melting of such material as wax for bandages.

PLANTINGS.

During the past year, the budded orchards have been increased by the successful transplanting of budded citrus and mango trees. Miscellaneous fruit and ornamental trees have been planted in their respective plats. The nurseries have been extended by plantings of citrus, mango, and avocado seedlings.

Cover crops as usual have been drilled into the orchards to hold the soil during the rainy season and to increase the humus content of the soil. The several varieties of cowpeas, pigeon peas, and jack beans that have been received during the year, as well as those varieties which have been segregated from seed collection, have been planted in plats for the production of seed.

SPRAYING.

Since the orchard trees are rapidly assuming mature proportions, it has become apparent that spraying operations could not be performed with the small, barrel spraying outfit. A double-acting cylinder spray pump that can maintain a pressure of 120 pounds or more per square inch has been secured. The outfit is complete with a 50-gallon barrel that has been fitted up with a mechanical agitator.

The avocado and mango orchards were sprayed once last fall.[1] These orchards have been sprayed once this season. The comparative freedom of the orchards from fungus disease shows that spraying is necessary and effective. The combined action of spraying and of the natural enemies has thus far kept the injurious insects well in control.

MAPPING.

One of the important lines of work undertaken this year was the revision of the field maps made in 1909. Some trees had died and many new ones had been placed in the orchards, making this revision imperative. Maps of these fields, by sections, have been bound by series in portfolios so that they are adapted to both field and office work. Every orchard tree has been labeled with a large painted tree label. After writing the number and name, the label was dipped in a thin solution of shellac, which insures its durability for some years.

A résumé of the maps shows that, excluding the Tantalus plantings, the hibiscus, and the windbreaks, we have the following trees:

Small citrus seedlings	1,436	Small avocado seedlings	308
Large citrus seedlings	191	Large seedling avocados	181
Budded citrus	184	Large budded avocados	15
Small mango seedlings	705	Large inarched avocados	7
Large mango seedlings	263	Small inarched avocados	5
Large budded mangoes	25	Figs	70
Large inarched mangoes	35	Papaya	490
Small inarched mangoes	20	Miscellaneous fruits	425
Ornamental trees	597	Ornamental shrubs	596

The budding work on the citrus seedlings has proceeded as in former years. This budding has not only required skill in placing the buds, but has demanded much attention in irrigation and in protection against ants, aphis, and scale insects.

The following varieties of budded citrus are now bearing fruit:

Oranges: Dancy, Golden Buckeye Navel, Mediterranean Sweet, Navelencia, Paper Rind, St. Michael, Ruby Blood, Satsuma, Thompson Improved Navel, Valencia Late, and Washington Navel.

Pomelos: Duncan, Marsh Seedless (California), Marsh Seedless (Florida), and Triumph.

Lemons: Eureka and Villa Franca.

Limes: Kusaie, Seedless, and Tahiti.

Miscellaneous: King Mandarin, Willow-leafed Mandarin, and citron of commerce.

THRASHING.

The amount of labor necessary to thrash and clean the seeds of legumes to be used for cover crops has become so great that a small power thrasher was secured. This machine can be successfully used for pigeon peas and cowpeas. Although it will thrash the jack bean, the beans have to be separated by hand from the refuse.

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[1] Hawaii Sta. Bul. 25, p. 24.

ACCESSIONS.

This department is continually receiving seeds and plants from various parts of the world. These are planted and, if subsequent testing proves their worth, the increase is distributed. Others of known value are immediately distributed. Among the accessions of the past year are a collection of passiflora plants and papaya seed from the Office of Seed and Plant Introduction; seeds of papaya varieties from the West Indian Islands, Central America, and Bolivia; varieties of roselle from Africa; onion seed from Madeira; and several varieties of cowpeas. The plantings of fiber Musas other than those of the true commercial Manila hemp have been made. Seedling plants of the Philippine variety, Maguindanao, grown at Washington, have been received. The plants which have been grown as *Carissa arduina* have been identified as *C. grandiflora.* Seeds of the true *C. arduina* are now germinating. The varietal collection of avocados has been increased by California, Kona, and Honolulu varieties, the latter being principally of described varieties.

DISTRIBUTIONS.

During the past year this department has filled requests for plants and seeds for many agricultural institutions. The public in general has requested material assistance, which has been granted whenever possible.

Several years ago this department secured seeds of an improved type of the so-called "Easter or Bermuda Lily," a cross between *Lilium longiflorum giganteum* and *L. multiflorum.* The transmission of fungus diseases is prevented by the use of seed. When the bulbs and plants were taken up this year several new plats were started. There is now a large number of plants from "scale" propagation on hand for distribution.

RECORDS.

From the time that accession records have been kept, these records show over 3,000 entries of seeds and plants. Seeds have failed to germinate, plants have not survived the struggle for existence, and others have served their usefulness. With the revision of the field maps came the task of bringing these records up to date. Instead of five chronologically arranged accession books there are now two, which include only live material. The corresponding index cards have been filed. The discarded index cards and the distribution cards have each been filed away for future reference.

MISCELLANEOUS.

At the poultry show practical examples of grafting and budding in all stages of manipulation and growth were shown. The fruits of budded citrus trees, together with the novelties that were in season, were displayed. The results of selection with the papaya were noteworthy. The demonstration of the various stages of practical plant breeding with the hibiscus promises to increase the number of amateur breeders. The exhibit of hibiscus flowers, averaging 200 or more daily, was a signal effort on the part of Mr. Holt.

The avocado trees in the Hilo district appear to be suffering, and a few recovering, from some fungus disease. The results of this attack, unusual rainfall during the blossoming period, the abnormal abundance of lichens, and the lack of judicial pruning have made the fruit scarce and lacking in quality. In the forest area of the "aa" flows which lie between Hilo and Puna are scattered avocado trees just coming into bearing. These trees have grown up from seed scattered by trainmen.

In Puna the avocado trees appear moderately vigorous, although they are planted in a somewhat dry soil. The fruits are reported to be watery, slightly fibrous, and to lack the usual agreeable flavor.

In Kona the avocado is not planted in orchard form, but is grown in dooryards and in and about the borders of coffee plantations where the pockets of soil are of a sufficient size. Kona produces much of the off-season fruit marketed in Honolulu. A few fruits were still in season. The trees with few exceptions are neglected.

REPORT OF THE ASSISTANT CHEMIST.

By WILLIAM McGEORGE.

The chief lines of work which have occupied the attention of the chemical department during the year are as follows: A continuation of investigations upon soil conditions and an accumulation of a large number of analyses of soils with the idea in view of publishing a general survey of Hawaiian soils. Several miscellaneous investigations and analyses have been made, also a chemical study of the sisal leaf and the waste accruing from decortication, and some further studies upon the rice plant, dealing in the main part with the sulphur and chlorin content.

SOILS.

About 150 samples of soil have been examined during the year, a large portion of which were taken in proposed new pineapple land on this island and the Haiku district of Maui. The prime factor in the examination of soils to be used in growing pineapples has been the determination of the manganese content, the deleterious effect of which has been thoroughly dealt with in previous publications of this station. At this point it may be of some interest to state that the highest manganese content of any soil examined from the islands, other than Oahu, has been a sample from Lanai which contained 1.13 per cent. However, comparatively few soils from the other islands have been examined and a more thorough survey during the coming year is contemplated. In the course of this soil work some further attention has been given to the sporadic type of soil mentioned in the last annual report, namely, that of abnormally high titanium content, and some rather important results have been obtained. Samples of this type have been collected from several districts upon this island (Oahu) and one district at Haiku, Maui, which contains 18.84 per cent TiO_2 in the soil and 20.02 per cent in the subsoil at a depth of 30 inches. The soil of highest content contained 34 per cent TiO_2. It is possible that the precipitate of TiO_2 contained other of the rarer metals in small quantities. However, it was free from iron and aluminum. It was not deemed worth while at this time to attempt a separation of the rarer metals, but it may possibly be done later. These soils are of a vastly different type, both chemically and physically, from any of the other soils found in Hawaii heretofore. The normal Hawaiian soils contain about 5 per cent TiO_2. Apparently the titanium is the most insoluble constituent of the Hawaiian soils. These titanium soils contain a strikingly smaller content of aluminum and a higher content of ferrous iron, which probably imparts to them the characteristic blue or gray color.

LYSIMETER EXPERIMENTS.

The application of lime to the soils of the Wahiawa district on this island has failed to produce any visible improvement in their tilth. However, this is not surprising, in view of the fact that the Hawaiian clays are of a very different character from those of other countries. In view of the above fact a set of lysimeter experiments was started to observe the effect, both chemical and physical, of lime. The chief reason for the application of lime as fertilizer is to correct soil acidity and to supply a basic element to combine with the organic acids formed in the decomposition of organic matter, thus maintaining the neutrality of the soil. Also it acts indirectly as a source of plant food, by rendering available small quantities of mineral matter, particularly phosphoric acid and potash. Mechanically it has the property of causing a flocculation of clay, so that when the soil becomes wet and is subsequently dried the lime acts as a cement, holding the particles of clay together in larger aggregates.

The four soils selected for use in these experiments were of very different types. No. 1 was a heavy clay soil from the Wahiawa district, No. 2 a soil of "intermediate" manganese content, No. 3 a heavy clay soil in badly puddled condition, and No. 4 a highly manganiferous soil. Twelve lysimeters were used, three for each type of soil, one of which was used as a check. To the second carbonate of lime was added and to the third sulphate of lime. Twenty-five pounds of air-dried soil were used in each lysimeter, and the lime added in such quantity as to make an addition of 0.1 per cent of CaO. In each instance the lime was thoroughly mixed with the soil and a small quantity of water added, to dampen the whole before placing in the lysimeter. The following chemical and mechanical analyses show the types of soil used:

Chemical analyses of soils.[1]

Constituents.	No. 1.	No. 2.	No. 3.	No. 4.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Titanic oxid (TiO_2)	2.25	0.03	0.50	0.68
Insoluble matter	39.26	40.66	38.22	31.67
Ferric oxid (Fe_2O_3)	24.33	14.99	27.89	18.60
Alumina (Al_2O_3)	14.65	19.71	13.86	14.67
Manganese oxid (Mn_3O_4)	.21	2.40	.10	9.21
Lime (CaO)	.50	.10	.05	1.32
Magnesia (MgO)	.36	.47	.80	.52
Potash (K_2O)	.49	.45	.34	.79
Soda (Na_2O)	.20	.22	.32	.38
Phosphoric acid (P_2O_5)	.06	.24	.14	.20
Sulphur trioxid (SO_3)	.08	.23	.17	.15
Volatile matter	13.65	15.75	12.17	16.78
Moisture	3.98	5.15	5.66	5.36
Total nitrogen	.32	.30	.31	.37

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[1] Analyses made according to official method.

Mechanical analyses of soils.[1]

	No. 1.	No. 2.	No. 3.	No. 4.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Soluble in dilute HCl	2.07	....	....	2.71
Moisture	3.51	5.15	5.66	5.46
Organic and volatile matter	12.68	15.75	12.17	15.86
Fine gravel	.00	.04	....	.82
Coarse sand	.75	1.53	.45	7.74
Fine sand	3.51	8.49	3.47	21.22
Silt	8.54	8.60	5.67	13.18
Fine silt	33.33	29.75	42.85	21.87
Clay	35.01	30.57	29.94	12.40

[1] Analyses made according to Hall, The Soil. London, 1908, 2. ed., p. 51.

The experiments were started on April 13, 1911, and water was added from time to time to replace that lost by evaporation. After eight months samples were taken from each of the lysimeters for analysis, to determine the water soluble and 1 per cent citric acid soluble constituents, this being deemed a better means of working on the soils than by treating the soil with water in the lysimeters and collecting the percolations for analysis. In the analysis 100 grams of soil were placed in a glass bottle and extracted with 1 liter of water, at room temperature, with occasional agitation, for one week. For citric acid soluble matter 100 grams were extracted, with 1 per cent citric acid solution for the same length of time. The results of the analyses are as follows:

Water soluble constituents in parts per million.

Soil No.	Lime added.	Lysimeter No.	Al_2O_3 Fe_2O_3.	Mn_3O_4.	CaO.	MgO.	Na_2O.	K_2O.	SO_3.	P_2O_5.
....	Check	1	18	7	53	16	39	49	39	13
1	$CaCO_3$	2	11	6	91	12	54	89	47	5
1	$CaSO_4$	3	17	22	531	28	51	62	248	8
2	Check	4	11	9	53	14	40	55	30	40
2	$CaCO_3$	5	12	7	143	11	59	56	52	14
2	$CaSO_4$	6	9	37	554	48	47	91	270	16
3	Check	7	21	7	74	16	65	69	27	30
3	$CaCO_3$	8	5	9	151	18	60	74	46	38
3	$CaSO_4$	9	5	36	464	39	33	66	268	15
4	Check	10	9	7	249	40	79	133	65	57
4	$CaCO_3$	11	9	10	383	47	77	108	83	55
4	$CaSO_4$	12	3	13	907	69	127	133	407	47

This table does not show any very striking chemical effects resulting from the use of the lime, but at the same time some of the effects are of interest. The usual chemical changes resulting from the addition of lime, namely, an increase in the solubility of the phosphoric acid and potash, were not effected, which, however, may be due to experimental discrepancies. In every instance except one the lime caused a decrease in water soluble phosphoric acid. In the majority of instances it effected an increase in solubility of potash. It is also interesting to note that in every instance the addition of sulphate of lime produced a marked increase in the solubility of the manganese and magnesium. The water soluble phosphoric acid was determined colorimetrically from a solution obtained by extracting 500 grams of the soil in 1 liter of distilled water.

Citric acid soluble constituents.

Lysimeter No.	Lime added.	Fe_2O_3.	Al_2O_3.	Mn_3O_4.	CaO.	MgO.	K_2O.	Na_2O.	P_2O_5.	SO_3.
		Per ct.	*Per cent.*	*Per cent.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	Check	0.136	0.410	0.003	0.030	0.058	0.034	0.034	0.0057	0.050
2	$CaCO_3$	.154	.440	.005	.075	.056	.026	.026	.0051	.054
3	$CaSO_4$	.147	.445	.007	.078	.060	.032	.032	.0077	.112
4	Check	.132	.839	1.484	.050	.088	.052	.052	.0077	.085
5	$CaCO_3$	.129	.839	1.456	.085	.090	.045	.045	.0038	.100
6	$CaSO_4$	.129	.812	1.507	.075	.110	.045	.045	.0025	.195
7	Check	.206	.434	.040	.040	.088	.094	.094	.0077	.064
8	$CaCO_3$	.192	.452	.026	.048	.072	.096	.096	.0051	.100
9	$CaSO_4$	.198	.481	.044	.062	.076	.077	.077	.0045	.140
10	Check	.055	.508	1.907	.110	.140	.130	.130	.0077	.090
11	$CaCO_3$	.055	.496	1.950	.157	.120	.145	.145	.0038	.065
12	$CaSO_4$	.065	.490	1.965	.147	.155	.151	.151	.0083	.185

Apparently, from this table, there is little regularity in the changes effected by lime as regards the citric acid soluble constituents. Phosphoric acid and potash were in some instances decreased, while in others there was an increase. The action of sulphate of lime was similar to that shown in the previous table; that is, it effected an increase in the solubility of the magnesium in every instance except one and an increase in the solubility of the manganese in every instance.

NITRATES AND AMMONIA.

It was also considered to be of sufficient importance to observe the changes in the nitrates and ammonia content at various intervals, produced by the lime, comparing the results with the check lysimeter. The results of these tests are given in the following table:

Variation in nitrates and ammonia in different lysimeters, parts per million.

Soil sample No.	Lysimeter No.	Lime added.	Nitrates.		Ammonia.	
			June 13, 2 months.	Nov. 13, 8 months.	June 13, 2 months.	Nov. 13, 8 months.
1	1	None	7.8	3.5	56.4	56.4
1	2	$CaCO_3$	7.3	6.9	33.6	28.2
1	3	$CaSO_4$	10.4	2.6	33.6	28.2
2	4	None	15.65	8.7	33.66	56.4
2	5	$CaCO_3$	17.85	1.3	39.6	28.2
2	6	$CaSO_4$	13.85	8.3	33.6	28.2
3	7	None	15.65	3.0	16.9	28.2
3	8	$CaCO_3$	25.00	4.4	16.9	42.3
3	9	$CaSO_4$	20.80	2.6	39.6	56.4
4	10	None	41.50	12.8	50.8	56.4
4	11	$CaCO_3$	17.85	10.5	39.6	56.4
4	12	$CaSO_4$	25.00	11.7	56.4	42.3

While the above tests do not duplicate field conditions, they indicate a great variation in nitrogen content and a striking decrease in nitrates upon standing in the lysimeter under normal climatic conditions. These tests also indicate the necessity of further work being carried on along this line before reaching any conclusion as to the effects of the different forms of lime upon the nitrate and ammonia content of these soils.

EFFECT OF LIME ON CAPILLARITY.

The only means the surface soil possesses by which it is able to replace the moisture lost on evaporation is capillarity. Of the several kinds of water existing in soils, the capillary form is probably the most important, for the above reason. It not only serves as a means of supplying moisture to the plant during dry weather, but also as a carrier for plant food. This capillary movement of moisture is caused by surface tension, and it is of some interest to know the effect of lime upon this property of the soil. Accordingly, a set of glass tubes, 2 centimeters in diameter, were fitted up and the rate of capillary rise and downward capillarity determined, with the following results:

Upward capillarity.

Soil sample No.	Time.								
	1 hour.	3 hours.	7 hours.	24 hours.	48 hours.	72 hours.	96 hours.	5 days.	6 days.
	Cm.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
1	14.0	19.5	25.0	32.75	....	41.25	43.5	45.75	47.5
2	14.5	20.5	26.75	35.5	....	43.75	46.0	48.0	49.5
3	12.75	18.5	24.0	30.25	....	36.5	38.0	40.0	41.25
4	19.5	24.5	30.0	37.5	42.5	46.0	48.25	50.5	53.5
5	18.5	23.75	29.25	37.0	42.0	44.5	46.5	48.25	50.5
6	16.0	21.5	28.0	36.25	39.75	41.5	42.75	44.0	45.5
7	9.75	14.5	18.25	24.0	....	30.5	31.75	33.0	34.25
8	9.75	13.25	17.5	23.25	....	28.5	30.25	31.5	32.25
9	10.5	13.5	17.25	23.25	....	27.75	29.5	30.75	32.0
10	20.0	26.5	34.5	46.0	52.0	56.0	59.5	61.75	65.25
11	19.0	26.5	33.25	42.5	46.5	49.0	51.0	52.75	55.0
12	19.5	26.5	33.25	43.0	49.25	53.0	56.0	58.0	61.0

In this table the capillary rise is shown to be more rapid where no lime had been added to the soil in every instance except that of soil No. 1, a heavy clay. The sulphate of lime decreases the rate of capillarity in every instance, and in all cases except the last the rate is less than that where carbonate had been used. In these experiments the glass tubes were allowed to stand in water, the end dipping about one-half inch into the water.

Downward capillarity.

Soil sample No.	Time required for disappearance of water below surface.	Penetration of water at time of disappearance from surface.	Final depth.	Soil sample No.	Time required for disappearance of water below surface.	Penetration of water at time of disappearance from surface.	Final depth.
	Hr. min.	*Cm.*	*Cm.*		*Hr. min.*	*Cm.*	*Cm.*
1	3 7	36.0	46.0	7	4 27	34.0	41.0
2	3 4	34.5	44.0	8	6 55	34.0	39.5
3	1 55	34.0	44.0	9	3 28	34.0	42.5
4	1 21	38.0	50.0	10	1 36	31.0	38.5
5	1 49	34.5	45.5	11	1 44	33.5	41.5
6	1 52	34.5	45.5	12	1 54	33.0	40.5

From this table it may be seen that the manganiferous soils, Nos. 2 and 4, are not greatly affected by the addition of lime beyond a slight decrease in the rate of downward movement of the water. The soil containing 2.4 per cent Mn_3O_4 (No. 2) showed a slight decrease in the depth to which the water reached, which indicates an increase in the absorptive power of the soil by use of lime. The highly manganiferous soil (9.2 per cent) showed the opposite effect, namely, an increase in depth to which the water reached and a decrease in absorptive power. A glance at soil No. 1 shows an increase in rate of downward movement of the water and also an increase in the absorptive power as a result of the addition of both forms of lime. But soil No. 3, which contains about 6 per cent less clay, shows a much more striking variation in rate of capillarity, but very little difference in the final depth to which the water reached. The rate of capillarity is strikingly less than that of any of the other soils and is an excellent example showing the effect of plowing these soils when they are too wet. The soil had become more colloidal than normally, due to puddling, and on drying assumed the form of very hard lumps which, on wetting again, were difficultly permeable to water. In these experiments 45 cubic centimeters of water was poured into the top of the glass tube.

FERTILIZER EXPERIMENTS WITH TARO.

In August, 1910, the station began some fertilizer tests on taro to determine the relative economic value of the use of fertilizers in various proportions and mixtures. These experiments were made in conjunction with the Kalihi Poi Factory and upon their taro plats. These experiments have been completed, and the data accumulated therefrom present some results of considerable practical value to taro growers, and in addition are of some scientific value.

The field was divided up into seven plats, each approximately one-twentieth of an acre in area. The fertilizer was applied on August 5 and the taro planted on August 15. To plat No. 1 superphosphate and sulphate of potash were added; to No. 2, nitrate of soda, superphosphate, and sulphate of potash; to No. 3 no fertilizer was added; No. 4, ammonium sulphate, superphosphate, and sulphate of potash; and No. 5 received ammonium sulphate only. The same fertilizer was applied to plats 6 and 7 as to No. 4 except that in the case of No. 6 it was applied on September 16, just before planting, while on No. 7 it was applied two months after planting in order to determine if the time of application would cause any great variation in results.

On August 29 the plants in plat No. 2 appeared to be about twice as large as the check plat, in plat 1 they were smaller, while in 4 and 5 they were about the same size as in the check plat. On September 12 the plants in plat 1 had assumed a yellowish color and were still smaller than those in the check plat. In plat 2 they were still larger than the check plat, but also were yellow. Plats 4 and 5 at this date showed great improvement, and the plants were larger than in any of the other plats and of better color, No. 5 appearing especially green. The final results of the experiments are shown in detail in the following table:

Effect of various fertilizers on taro.

No. of plat.	Fertilizer applied.	Amount per acre.	Yield of taro.	Yield of poi.	Percentage of poi in taro.
		Pounds.	*Pounds.*	*Pounds.*	
1	Superphosphate	450	1,499	1,050	70.0
	Sulphate of potash	450			
2	Nitrate of soda	400	1,751	1,010	57.6
	Superphosphate	450			
	Sulphate of potash	400			
3	No fertilizer	....	1,231	920	74.7
4	Ammonium sulphate	300	1,702	1,270	74.6
	Superphosphate	450			
	Sulphate of potash	400			
5	Ammonium sulphate	300	1,215	800	65.8

These experiments, while they were carried through only one season, indicate the economic value to be derived from the application of ammonium sulphate, superphosphate, and sulphate of potash to taro. In the second column are shown the weights in pounds per acre, the plats used being only one-twentieth of an acre in size; hence only one-twentieth of these weights were applied on each plat. The yields of taro and poi are given in pounds per plat and not in acreage figures. The weight of taro does not include leaves, but only the marketable root bulbs. Column 5 represents figures obtained in factory.

It is clearly evident from these results that the effect of nitrate of soda is to produce a bulb of greater weight and volume than any of the other fertilizers, but in so doing it causes a decrease in carbohydrate content, from which some doubt arises as to its economic value as a fertilizer, even though it produced 90 pounds more poi than the check plat. The mixture used in plat No. 4, namely, ammonium sulphate, superphosphate, and sulphate of potash, while it produced an increased yield of 350 pounds poi more than the check plat, does not produce an abnormal growth of the plant as in plat No. 2. This is shown by the fact that there is only 0.1 per cent difference in the percentage of poi in taro obtained from this plat and the check plat, which indicates the normal development of carbohydrates in the root bulb, which results are to be desired in all fertilizer applications.

The fact that taro is grown under soil conditions similar to those in which rice is grown suggests the possibility of these plants having the property of assimilating nitrogen in a somewhat similar form. It has been shown [1] that rice is unable to properly assimilate nitrogen when added in the form of nitrates, while on the other hand ammonium sulphate supplies the nitrogen in a form which produces a considerable increase in yields of both straw and grain. However, in the case of taro the nitrate produces a slightly larger root than the sulphate of ammonia, but less starch.

Plats 6 and 7 showed practically no difference in yield, indicating that no difference results from delaying the application of the fertilizer for two months. Also the yield of these plats was practically the same as that from plat No. 4.

SISAL.

During the year a brief study was made of the chemical composition of the sisal plant with a view to ascertaining some possible means of utilizing the enormous waste accruing from the decortication of the leaves. The results of this work have been published in a recent press bulletin.[2] The most attention was given to sisal and henequen, which are cultivated commercially in Hawaii. Investigations were made to determine their value as fertilizer, stock food, and as a possible source of industrial alcohol. Also a quite extensive chemical analysis of the leaves was made.

The most important finding brought out during the work was the identification of the normal acid of the leaf as lactic acid. So far as the author has been able to ascertain, the normal acidity of the leaf has never been determined. F. H. d'Hérelle [3] attributes the strong acidity of the leaf to oxalic acid, which he says is present in part. It is a very noticeable feature of the sisal fiber industry that the corroding of the machinery due to the strong acidity of the leaf is a factor to be considered, which has been overcome to a certain extent by the use of an especially prepared alloy. The Hawaiian Fiber Co. was desirous of knowing the identity of the acid and the possibility of its commercial value. The result was the discovery of lactic acid, as mentioned above.

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[1] Hawaii Sta. Bul. 24.

[2] Hawaii Sta. Press Bul. 35.

[3] Jour. Agr. Trop., 10 (1910), No. 108, pp. 161-167.

The result of the investigation indicates that obviously the best means of utilizing the waste is to return it to the soil as fertilizer. Although the manufacture of industrial alcohol is worthy of consideration, it is by no means promising, owing to the difficulties to be overcome in fermentation and the comparatively low carbohydrate content of the plant, which was found to be only 2 to 7 per cent of the fresh leaf.

EFFLORESCENCE ON LAVA BRICKS.

Among the miscellaneous investigations undertaken by the laboratory within the past year was one upon the occurrence of an efflorescence upon bricks made from ground lava rock. While it does not strictly represent an agricultural industry, still it was considered to be worth an investigation, being related in a way to the study being carried on in the laboratory upon lavas, their disintegration, etc.

The efflorescence was found to be composed of the carbonates or bicarbonates of sodium and potassium, which in some instances have been found to make their appearance in such large quantities as to give a wall made of these bricks the appearance of having been in the path of a snowstorm. So far as the author has been able to find out, these alkali carbonates have never been known previously to appear in this form, nor in such large quantities as an efflorescence.

The brick are made by pressing the ground rock after a slight addition of lime and dampening of the mixture. They are then dried under steam pressure. The conclusion reached was that the lime and the subsequent drying temperature cause the trouble. Sodium and potassium carbonates are not normal products of lava disintegration, although some of the vesicles in lava rock contain a coating of carbonate. Potassium and sodium occur in basaltic lava in the form of complex silicates. The lime at the temperature of the drying kiln probably replaces the sodium and potassium in these silicates and forms caustic soda and potash, which in turn are converted on contact with the air into carbonates and bicarbonates. This work has been presented to the Journal of Industrial and Engineering Chemistry for publication in more complete form.

SUNLIGHT.

The Philippine Bureau of Science for several years past has been engaged in an extensive investigation of tropical sunlight, paying especial attention to the actinic rays. At the request of this bureau the station has carried on a series of experiments extending over a period of one year to test the actinic power of the sun in Hawaii.

The theory has been prevalent that the sun's rays may be divided into classes of which the blue, violet, and ultra-violet rays are actinic, that is, capable of producing chemical reactions; also that these rays are a factor of great importance in relation to the effect of insolation on the white man in the Tropics. As a means of measuring this actinic power, Dr. R. F. Bacon, of the bureau of science, has utilized a solution of oxalic acid in the presence of uranium acetate. The latter compound acts as a catalyzer and eliminates the error which would ensue from side reactions, such as oxidation or formation of peroxid. The oxalic acid is decomposed by the actinic rays of the sun and the residual oxalic acid determined by titration.

DESCRIPTION OF THE EXPERIMENTS.

The following solution was exposed, in a Jena glass flask, to the direct rays of the sun, the flask being placed away from reflecting walls and on a sheet of dull black paper: Five cubic centimeters of a 1 per cent solution of uranium acetate, 5 cubic centimeters of a 10 per cent solution of oxalic acid, and 20 cubic centimeters of distilled water. This solution was exposed as above from 9 to 12 o'clock a. m. The solution was then titrated with N/10 potassium permanganate, after addition of 25 cubic centimeters of 1:5 sulphuric acid and heating to 60° C. From this titration the percentage of oxalic acid decomposed was determined. The permanganate solution was standardized quite often and all solutions kept stored in a dark place. Also the same flask was used throughout the year, as it was found that the results are affected slightly by using different flasks. It is hardly necessary to present the results in detail, but only the more important points will be brought out.

Maximum, minimum, and mean actinic power.

Month.	Maximum.	Minimum.	Mean.	Month.	Maximum.	Minimum.	Mean.
January	52.20	11.31	36.41	July	50.55	16.59	37.25
February	50.13	18.88	40.49	August	55.53	27.25	43.75
March	53.28	10.46	41.47	September	62.33	19.72	46.49
April	53.98	16.37	42.92	October	54.81	24.74	44.89
May	52.92	23.67	41.56	November	53.07	17.76	42.77
June	52.25	19.86	40.94	December	48.72	19.24	35.35

Column 1 shows the maximum decomposition obtained during the month, in column 2 the figures represent the minimum actinic power for that month, column 3 represents the mean monthly actinic power of the sun. That is, the daily percentage decompositions were added up for each month and the sum total divided by the number of days on which the actinic power was measured. The following curve (fig. 2) illustrates more plainly the variation of the actinic power of the sun throughout the year in Hawaii.

The above curve presents some very striking data, from which it may be readily seen that the actinic power of the sun is governed apparently by the position of the sun relative to the earth rather than such climatic factors as the rainy season or the hotter months of the year. The fact that the hotter months, namely, June and July, are so extremely low in actinic power further substantiates the finding of other investigators, namely, that the heat rays are not actinic, or at least only slightly so.

It is highly probable that the position of the sun at various stages of the earth's circuit around the sun is a factor to be taken into consideration. On March 21 and September 21 the sun is directly over the equator, and the curves for these months show the highest points for the first half and second half of the year. In like manner on June 21 and December 21, the months in which the sun reaches its longest distance above and below the equator, respectively, these points on the curve are the lowest and of least actinic power.

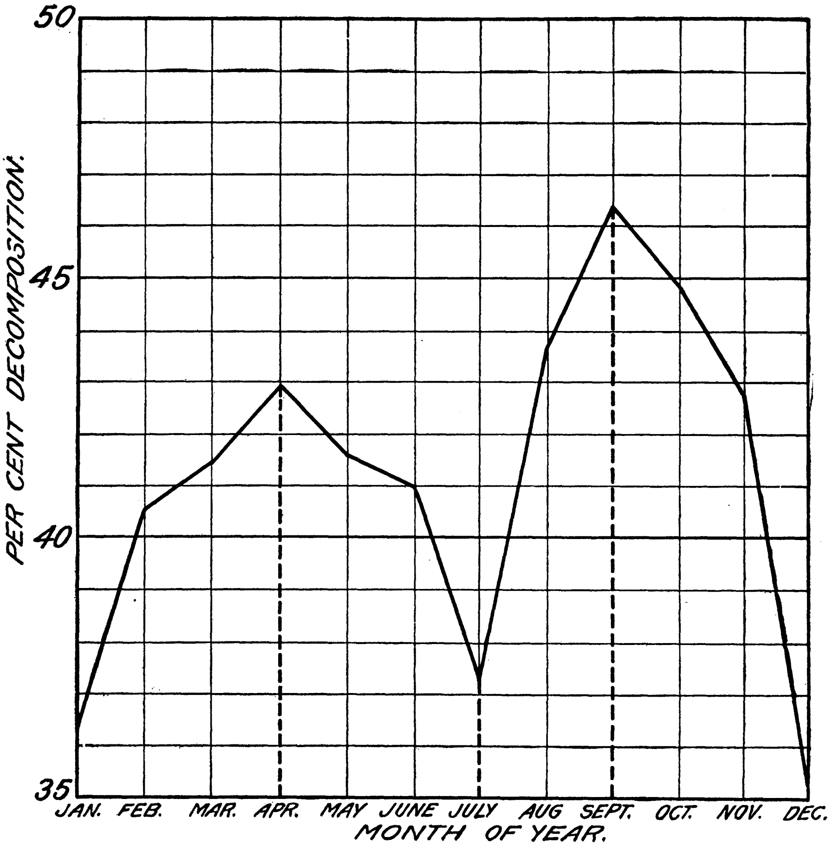

FIG. 2.—Actinic power of sunlight.

It has been found in the investigation that the lowest actinic days are those on which it is raining and cloudy. The mere fact that the day is cloudy, however, does not necessarily indicate a nonactinic day, as we have found cloudy days on which it is as strong as on many sunshiny days, indicating that the actinic rays to a great extent pass through the clouds. Sunshiny days vary considerably, some being actinic while others are much less so. Quite often hazy days were found to be very strongly actinic but like the sunshiny days, they were not regularly so. It was found to be a regular occurrence that a sunshiny day following a rain of the night before produced very strong actinic rays. For a short time tests were also run in the afternoon from 12 to 3 p. m., and it was found that the afternoon rays were more strongly actinic than the morning rays. That the points on the curve for the first half of the year are so much lower than those of the latter half is probably due to the fact that these months represent the rainy season, during which there were fewer sunshiny days, thus lowering the monthly average, even though the actinic days during this season were less actinic than those of the latter half.

MISCELLANEOUS.

A small amount of miscellaneous analytical work has been done during the year, among which were some analyses of Hawaiian rubber. The following table shows the maximum and minimum results obtained from the analyses of seven samples of crepe form, and represents the average composition of Hawaiian rubber:

Composition of Hawaiian rubber.

Constituents.	Minimum.	Maximum.	Constituents.	Minimum.	Maximum.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Protein	2.62	3.81	Ash	0.78	1.65
Resin	3.06	4.18	Gum	90.93	92.65
Moisture	.49	.89			

A comparison was also made of the composition of the crepe and biscuit forms of Hawaiian rubber and a sample of Malay crepe rubber, with the following results:

Comparison of crepe and biscuit rubber.

Constituents.	Malay crepe.	Hawaiian crepe.	Hawaiian biscuit.	Constituents.	Malay crepe.	Hawaiian crepe.	Hawaiian biscuit.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
Proteids	3.50	3.25	5.37	Ash	0.37	1.13	1.40
Resin	2.67	3.55	3.08	Gum	92.84	91.40	88.86
Moisture	.62	.67	1.29				

Hawaiian rubber is shown to contain a higher percentage of ash and resins than the Malay rubber, the latter probably being due to a difference in the age of the trees as it is known that the resin content of some rubbers decreases as the age of the tree increases. The higher percentage of proteids in the biscuit form is due to the greater pressure under which the crepe rubber is washed.

Another analysis of some importance was that of the trunk of the fern tree (*Cibotium chamissoi*), which is being used to a certain extent as a hog feed, both raw and cooked, on the island of Hawaii. It occurs in immense quantities in districts of Hawaii and its utilization is a factor in the clearing of forests. An analysis has also been made of a sample of soy-bean cake.

Comparative analyses of fern tree trunks and soy-bean cake.

Constituents.	Fern.	Fern (dry basis).	Soy-bean cake.	Constituents.	Fern.	Fern (dry basis).	Soy-bean-cake.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
Moisture	69.38		15.62	Starch	20.92	68.32	
Ash	.33		24.52	Fat			18.76
Nitrogen	.18		2.76	Sodium chlorid			23.05
Protein	1.12	3.65	17.25	Nitrogen free extract and crude fiber			23.77
Phosphoric acid	.10	.32	.08				
Reducing sugar	3.99	13.03					
Nonreducing sugar	.24	.78					

The high percentage of salt to be found in the soy-bean cake is due to the large quantities added during the fermentation which the mash undergoes in the process of soya sauce manufacture.

THE DETERMINATION OF SULPHUR AND CHLORIN IN THE RICE PLANT.

By ALICE R. THOMPSON, *Assistant Chemist.*

In so complex an organism as one of the higher plants it is difficult even to suggest correctly the functions of the various elements found in it. Besides many other investigations, Loew[1] has defined the uses of phosphoric acid, sulphur, and chlorin in the plant.

Phosphoric acid is found in organic compounds such as lecithin, inosite, hexaphosphate, nuclein, and chlorophyll; also in inorganic form as calcium, magnesium, and potassium phosphate. Inorganic phosphate is found in small quantities in the foliage of plants, while the seeds contain almost no mineral phosphate, but usually large amounts of phosphorus in organic combination.[2]

Sulphur is also found in definite chemical organic compounds in the plant. Osborne,[3] who analyzed a large number of sulphur albuminoids in seeds, found sulphur in constant molecular amounts in the various purified substances he obtained. For instance, edestin contains 0.884 per cent SO_3, legumin, 0.385 per cent; gliadin of wheat, 1.027 per cent.

Sulphur also occurs as mustard oils in plants; mustard seed and onions are common examples of plants containing these oils.

Sulphur in mineral form as sulphates occurs usually in smaller quantities in plants. Arendt, Ulricht, E. Schulze, Berthelot and Andre, and Fraps[4] investigated the mineral form of sulphate in plants and found it to vary in different parts of the plant as well as in plants belonging to different families. Sulphates are also formed from the organic sulphur in germinating seeds.

Euler[5] believes that sulphur is held in reserve form in the plant as cystin, a dithio-diamido-dilactic acid—

$$\begin{array}{l} S-CH_2-CH\ (NH_2)\ COOH \\ S-CH_2-CH\ (NH_2)\ COOH \end{array}$$

which is an exceedingly energetic compound, from which hydrogen sulphid is split off in small but continuous amounts for the formation of albuminoids.

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[1] U. S. Dept. Agr., Div. Veg. Physiol. and Path. Bul. 18.

[2] New York State Sta. Tech. Bul. 1, p. 7.

[3] Connecticut State Sta. Rpt. 1900, pp. 442–471; Jour. Amer. Chem. Soc., 24 (1902), No. 2, pp. 140–167.

[4] North Carolina Sta. Rpt. 1903, p. 67.

[5] Grundlagen und Ergebnisse der Pflanzenchemie. Brunswick, 1909, pts. 2–3, p. 146.

Whether or not chlorin is a necessary ingredient of plants is quite unknown. Many investigators believe the presence of chlorin to be superfluous in plants. As chlorin is present in most soils as the very soluble salts of sodium, potassium, and magnesium, the plant absorbs it as it absorbs any soluble salt in the soil. Also, if chlorin be present in considerable amounts, it acts as a strong poison to the plant. Euler[1] points out that no organic compound containing chlorin in molecular combination has been isolated from any plant. Nobbe, Siegert, et al.,[2] in their experiments with buckwheat, showed that chlorin is required in this instance to carry the plant to maturity. Many believe that it is necessary for the translocation of carbohydrates, helping to render starch more soluble. Others (A. Mayer[3]) hold that even buckwheat can be brought to maturity without chlorin.

In this paper the author has sought to show the sulphur and chlorin content of the parts of the rice plant at three stages of growth, and to determine the effect, if any, of fertilizer on the sulphur and chlorin composition of the plant grown in natural soil conditions and in sand cultures; also to determine the amounts of sulphur and chlorin contained in the rice field soil and water. The phosphoric acid content of the plant has been given in a previous publication.[4]

From the obvious increase of sulphate ions in rice plants grown in silica sand and fertilized with ammonium sulphate, conclusions may be drawn that ammonium sulphate as such is absorbed by the plant. Free ammonia was found in the foliage of plants grown in the rice fields, and, as has been shown in a bulletin of the station,[5] the rice plant makes the best growth when nitrogen is supplied in the form of ammonia.

METHOD OF ANALYSIS.

The method followed in the analysis of the rice samples for total sulphur is that of Osborne,[6] slightly modified by Hart and Peterson[7] in that the water was not boiled off from the saturated sodium hydroxid solution and the melt from the sodium peroxid fusion of the rice sample was boiled out with water and not with acid. The author found that not enough emphasis has been placed on the influence of sulphur from the gas burners on sulphur determinations. In the first analyses made, the fusions were made over alcohol lamps, but the solutions were boiled in beakers covered with watch glasses over gas burners. The resulting blank determinations were high in sulphur, amounting to 0.03 per cent SO_3. All subsequent determinations were therefore made in a room shut off from gas fumes and both fusion and boiling made over alcohol lamps. The resulting blank determinations were practically nil in sulphur, as shown below:

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[1] Loc. cit.

[2] Landw. Vers. Stat., 4 (1862), pp. 318–340; 7 (1865), pp. 371–386; 13 (1871), pp. 330–400; cited by Euler, Grundlagen und Ergebnisse der Pflanzenchemie. Brunswick, 1909, pts. 2–3, p. 149.

[3] Jour. Landw., 49 (1901), No. 1, pp. 41-60.

[4] Hawaii Sta. Bul. 21.

[5] Hawaii Sta. Bul. 24.

[6] Loc. cit.

[7] Wisconsin Sta. Research Bul. 14, p. 2.

Blanks on sodium peroxid.

	Per cent SO_3.
Fused over alcohol lamp but solution boiled over gas flame	0.0009
Fused and solution boiled over alcohol lamps	.0001

Blank on reagents bromin and nitric acid negligible.

In acidifying the alkaline solution of the fused melt it was noticed that a very good indication of the neutral point was the continuous effervescence due to carbon dioxid or hydrogen peroxid gas that occurs just after the solution becomes acid.

Before this stage is reached the effervescence resulting from addition of acid does not continue when addition of acid ceases.

The precipitate of barium sulphate was treated with hydrofluoric acid and a few drops of sulphuric acid and ignited a second time to remove traces of silica that in a few cases contaminated the precipitate.

Duplicates on each sulphur determination were made and checked usually within 0.02 and 0.03 per cent.

The mineral sulphur was determined by stirring the sample with 100 cubic centimeters of cold 1 per cent hydrochloric-acid solution and allowing it to stand an hour before filtering. (In the case of the starchy grain the sample was boiled with the solution to render it soluble. No hydrolysis of sulphate occurred by this method, as no trace of sulphate was ever found in the grain.)

Chlorin was determined by the Volhard method (official method).[1]

The samples of rice plants for this work were collected March 23, April 19, and May 15, 1912, 10 clumps of the plants being selected from each of two plats at the trial grounds. The first series of plants was taken before the flowering and divided into foliage and roots for analysis. The second series was taken at the time of full-stage flowering and divided into panicles, leaves, stems, and roots. The third series was taken at maturity and divided into grain, chaff, leaves, stems, and roots. This plan follows that given in a previous publication of this station.[2]

The plats from which the rice was taken were the unfertilized and the complete ammonium sulphate fertilizer plats.

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[1] U. S. Dept. Agr., Bur. Chem. Bul. 107 (rev.), p. 23.

[2] Hawaii Sta. Bul. 21.

RESULTS OF ANALYSES.

The following table shows the sulphur and chlorin composition of the rice plant at the first harvest and compares the composition of plants grown in the two plats; one unfertilized, the other fertilized with ammonium sulphate, superphosphate, and potassium sulphate.

Sulphur and chlorin in rice at the first harvest.

(Water-free basis.)

	Check plat.			Complete fertilizer plat.		
	Foliage.	Roots.	Total plant.	Foliage.	Roots.	Total plant.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Total SO$_3$	0.489	0.492	0.491	0.393	0.430	0.401
Mineral SO$_3$	.057	.208	.107	.079	.188	.102
Cl	.628	1.090	.780	.605	.949	.679

In this series the total sulphur percentage is higher than at any other period of growth. It is about equally distributed between the foliage and roots. In the samples from the check plat the total sulphur trioxid is about 0.1 per cent higher than it is in those from the complete fertilizer plat. This may be due to the fact that the plants in the complete fertilizer plat were much larger and had made more growth.

The percentage of mineral sulphur is highest in the roots, being almost four times as high in the roots as in the foliage; but it is much less than the total sulphur, showing the formation already made of organic sulphur in the plant. Chlorin is also highest at this first period and, like sulphur, is found in largest percentage in the roots.

Sulphur and chlorin in rice at the second harvest.

(Water-free basis.)

	Check plat.					Complete fertilizer plat.				
	Panicles.	Leaves.	Stems.	Roots.	Total.	Panicles.	Leaves.	Stems.	Roots.	Total.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Total SO$_3$	0.245	0.395	0.169	0.305	0.2453	0.245	0.344	0.157	0.313	0.2294
Mineral SO$_3$	.000	.056	.009	.143	.0374	.000	.037	.036	.162	.0517
Cl	.200	.370	.349	.490	.3534	.174	.345	.352	.446	.3437

At the second period the difference in composition of the plants grown in the two different plats has become nil and no effect of fertilizers is shown in the percentage composition, although the plants were much larger and heavier in the complete fertilizer plat.

The percentage of sulphur in the total plant has decreased from the first period, the leaves having the highest content in sulphur, the stems lowest.

No mineral sulphur was found in the panicles, but this form was relatively high in the roots and leaves.

Chlorin had also decreased in percentage amount and was quite low in the panicles and high in the roots.

Sulphur and chlorin in rice at the third harvest.

(Water-free basis.)

	Check plat.						Complete fertilizer plat.					
	Chaff.	Grain.	Leaves.	Stems.	Roots.	Total plant.	Chaff.	Grain.	Leaves.	Stems.	Roots.	Total plant.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
SO_3	0.166	0.241	0.256	0.126	0.247	0.1933	0.118	0.231	0.195	0.120	0.292	0.1763
Mineral SO_3	.000	.000	.000	.000	.087	.005	.000	.000	.000	.000	.121	.008
Cl	.261	.040	.338	.605	.376	.306	.246	.038	.419	.522	.392	.314

At the third period the fertilizers show no effect on the composition of the plant.

Total sulphur is very small in the stems and chaff and about 0.23 per cent in the other parts of the plant.

Mineral sulphur is found only in the roots, showing that the plant has used up the mineral sulphur in the formation of organic material.

Chlorin is practically absent from the grain, though high in the stems.

Mature rice plants from plats under different fertilizer conditions were selected, 10 clumps from a plat, and analyzed separately to determine any influence of fertilizer on the sulphur, chlorin, or phosphoric acid composition on the straw and paddy of rice. In the following table the results show no difference in the sulphur or chlorin composition of these plants grown in the different plats. The ammonium sulphate plat shows a slight depression of the phosphoric acid absorbed by the rice plant.

Sulphur, phosphoric acid, and chlorin in rice plant.

[Water-free basis.]

Fertilizer.	No. of plat.	Straw.			No. of of plat.	Grain.		
		Total SO_3.	P_2O_5.	Cl.		Total SO_3.	P_2O_5.	Cl.
		Per ct.	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	*Per ct.*
Check	24	0.204	0.278	0.445	34	0.255	0.926	0.058
Sulphate of potash, superphosphate	25	.193	.215	.449	35	.262	.954	.045
Ammonium sulphate, sulphate of potash	26	.189	.291	.461	36	.228	.861	.044
Ammonium sulphate, superphosphate	27	.207	.231	.511	37	.249	.879	.054
Check	28	.171	.245	.478	38	.247	.900	.051
Ammonium sulphate, superphosphate, sulphate of potash	29	.162	.255	.502	39	.254	.824	.056
Ammonium sulphate, superphosphate, sulphate of potash	30	.191	.242	.544	40	.235	.813	.050
Ammonium sulphate	31	.199	.240	.544	41	.250	.815	.046

The following table shows the amount of sulphur, chlorin, and phosphoric acid absorbed from the soil by the rice plant and indicates the possibility of sulphur fertilizations being required by a crop that absorbs about half as much sulphur as it does phosphoric acid for organic material.

That considerable amounts of sulphur are removed by various crops from the soil is shown by Hart and Peterson[1] who suggest the need of fertilization of soils by sulphur.

Boullanger[2] showed the favorable effect of sulphur on the bacterial condition of the soil. Demolon[3] obtained increased yields by the use of flowers of sulphur as fertilizer and believes it is transformed into sulphates in the soil. Bernhard[4] also secured larger crops by the use of sulphur fertilizer.

Amount per acre of sulphur, phosphoric acid, and chlorin absorbed by the rice plant.

	Check plat.	Complete fertilizer plat.		Check plat.	Complete fertilizer plat.
	Pounds.	*Pounds.*		*Pounds.*	*Pounds.*
SO_3	9.5	11.9	Calculated as S	3.8	4.8
Cl	14.9	21.1	Calculated as P	12.6	18.4
P_2O_5	28.8	42.0			

A partial analysis of the soil obtained at the rice trial grounds is shown in the table below:

Analysis of the soil obtained at the rice trial grounds.

	Per cent.
Total SO_3 (Osborne method)	0.123
Acid soluble SO_3 (official method)	.031
Water soluble (1 per cent HCl.)	.008
Acid insoluble residue SO_3 (Osborne method)	.022
Iron precipitate from official soil solution (Osborne)	.032
Steam distillation of soil, SO_3 determination	.001
Moisture	5.58
P_2O_5	.671
Cl	.016

In the Osborne method of determination, the melt solution was filtered in an alkaline condition so that the iron and titanium were separated from the solution in which the sulphate was precipitated. No ammonium salts were thus introduced, and ferric chlorid was eliminated.[5] In the official method, however, the iron was precipitated by ammonia in the cold, according to Treadwell,[1] so that no basic iron sulphate would tend to form.

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[1] Wisconsin Sta. Research Bul. 14, p. 5.

[2] Compt. Rend. Acad. Sci. [Paris], 154 (1912), No. 6, pp. 369, 370.

[3] Ibid., No. 8, pp. 524-526.

[4] Deut. Landw. Presse, 39 (1912), No. 23, p. 275.

[5] North Carolina Sta., Rpt. 1902, p. 50.

The results indicate that the sulphur in the soil is present largely in organic form, since the acid soluble and water soluble sulphur are relatively so small. No trace of sulphid was found on boiling the soil with hydrochloric acid. Doubtless the presence of large amounts of iron in the soil results in the formation of insoluble basic compounds of sulphur and this may explain the noneffect of sulphur fertilizer on the composition of rice plants grown in the soil, for, as will be seen later, in silica sand cultures, the composition is much affected.

The soil was subjected to steam distillation and only 0.001 per cent SO_3 in the distillate was found oxidized with bromin.

The soil contains an abundance of phosphoric acid but no large amount of chlorin.

In the following table is shown the composition of the water entering the rice field and the water standing on the last plat.

Analyses of water used on rice fields.

Constituents.	Artesian water entering rice trial grounds.	Water from last plat in field.	Rain water collected at experiment station.
	Parts per million.	*Parts per million.*	*Parts per million.*
CaO	6.5	6.6	
MgO	8.7	10.1	
Cl	73.8	63.9	
SO_3	8.8	9.0	3.41
NH_3	None.	Trace.	

This irrigation water flows over the field and amounts to 25,700 gallons per acre per day and doubtless the plant obtains some of its chlorin and sulphur from the water standing about its roots.

Sulphur trioxid amounted to about 9 parts per 1,000,000 and chlorin to 70 parts per 1,000,000.

Analysis of rain water collected at the experiment station showed 3.41 parts per million of SO_3. But as the rice trial grounds are situated farther from the hills, they received almost no rainfall this year and the soil would receive no sulphur from this source.

The author took advantage of samples of rice grown in pot cultures for nitrogen work as outlined in Bulletin No. 24 of this station. The plants had received in addition to a basic fertilizer lacking nitrates, as given by MacDougal,[2] calcium sulphate and the several forms of nitrogen as shown in the table.

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[1] Analytical Chemistry.—Quantitative Analysis. New York and London, 1909, 1. ed., vol. 2, p. 282.

[2] Text-book of Plant Physiology, New York, 1901, p. 225.

Total sulphur as SO_3 in moisture-free material (pot cultures).

Fertilizer.	Straw.			Paddy.		
	Trial grounds, submerged.	Silica sand, submerged.	Silica sand, not submerged.	Trial grounds, submerged.	Silica sand, submerged.	Silica sand, not submerged.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Check	0.215	....	....	....	....	....
$(NH_4)_2SO_4$	.239	0.667	0.449	0.328	0.405	0.444
$Mg(NO_3)_2$	.221	.380	.262	....	.318	....
$NaNO_3$	.388	....	.274	.263	....	....
$Ca(NO_3)_2$	.267	.343	....	.319	....	....
NH_4NO_3	....	.508	.310	....	.294	....
$(NH_4)_3PO_4$	....	.341	....	....	.302	....
Soy bean cake	....	....	....	.327	....	....

In this table no consistent influence can be seen on the sulphur composition of the plants grown in pots containing trial-ground soil. But in those plants grown in the silica-sand pots the total sulphur content is higher in every case and constantly higher when the soluble ammonium sulphate was the fertilizer added. In the following table the mineral sulphur in the plants is shown.

Mineral sulphur as SO_3 in the plants.

Fertilizer.	Straw.			Paddy.		
	Trial grounds, submerged.	Silica sand, submerged.	Silica sand, not submerged.	Trial grounds, submerged.	Silica sand, submerged.	Silica sand, not submerged.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Check	0.052	....	....	....	....	....
$(NH_4)_2SO_4$	.106	0.435	0.148	None.	None.	....
$Mg(NO_3)_2$	.069	.163	.070	....	None.	....
$NaNO_3$	.698	....	.076	None.	....	....
$Ca(NO_3)_2$	.061	.152	....	None.	....	....
NH_4NO_3	....	.309	.098	....	None.	....
$(NH_4)_3PO_4$	....	.175	....	....	None.	....
Soy bean cake	....	....	....	None.	....	....

These results indicate the increase of total sulphur in the straw to be almost entirely due to mineral sulphur absorbed by the plant.

Phosphoric acid in moisture-free plants.

Fertilizer.	Straw.			Paddy.		
	Trial grounds, submerged.	Silica sand, submerged.	Silica sand, not submerged.	Trial grounds, submerged.	Silica sand, submerged.	Silica sand, not submerged.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Check	0.227	....	....	....	....	....
$(NH_4)_2SO_4$	.176	0.162	0.285	0.784	0.849	0.924
$Mg(NO_3)_2$	.247	.262	.296	....	.761	....
$NaNO_3$	.190	....	.253	.812	....	....
$Ca(NO_3)_2$	.207	.200	....	.671	....	....
NH_4NO_3	....	.158	.252	....	.750	....
$(NH_4)_3PO_4$	....	.201	....	....	.802	....
Soy bean cake	....	....	....	.836	....	....

The phosphoric acid content was found to be fairly constant throughout this series of plants.

In the table given below are the analyses of plants grown by the author in silica-sand pots with the view of verifying the previous results. The chlorin absorbed was about twice as high as that absorbed by the rice plant grown in normal soil conditions. These results with silica-sand cultures show the sulphur fertilizer is not rendered insoluble to the plant as is the case in soil cultures. They show the probability of the absorption of ammonium sulphate as such by the rice plant as so much mineral sulphate is found in the foliage, and free ammonia was determined in the water solution of two rice-plant samples.

Plants grown submerged in silica sand.

	Ammonium sulphate.	Calcium sulphate.	Check.
	Per cent.	*Per cent.*	*Per cent.*
Total SO_3	0.852	0.531	0.409
Mineral SO_3	.629	.312	.095
Cl	1.231	.969	1.266

The author made some determinations of phosphoric acid in the solutions obtained from sulphur determinations by fusion with sodium peroxid. The molybdic precipitate was dissolved and reprecipitated to exclude silica. The results as given in the following table compare favorably with those obtained by ignition with magnesium nitrate (official method):

Content of phosphoric acid as shown by different methods.

Number.	Na_2O_2 method.	Air-dried material, $MgNO_3$ method.
	Per cent.	*Per cent.*
8 (grain)	0.731	0.726
9 (straw)	.163	.138
12 (straw)	.261	.223
15 (grain)	.626	.593
18 (straw)	0.272	
35 (grain)	.740	0.771
36 (grain)	.702	.842

Also results obtained by boiling samples with HCl and HNO_3 compared with those obtained by boiling with H_2SO_4 and KNO_3 (official method)[1] are as follows:

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[1] U. S. Dept. Agr., Bur. Chem. Bul. 107 (rev.), p. 2.

Content of phosphoric acid as shown by different methods.

Number.	Straw.		Number.	Grain.	
	H_2SO_4-KNO_3 method.	HCl-HNO_3 method.		H_2SO_4-KNO_3 method.	HCl-HNO_3 method.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
24	0.255	0.189	34	0.831	0.249
25	.197	.201	35	.842	.225
26	.266	.182	36	.771	.223
27	.212	.198	37	.781	.216
28	.294	.202	38	.803	.255
29	.233	.164	39	.730	.212
30	.222	.154	40	.725	.221
31	.220	.188	41	.727	.230
32	.260	.268	42	.778	.245
33	.267	.199	43	.771	.223

It is evident that the results obtained from the straw analyzed by the two methods are not greatly different, but those obtained by boiling the grain with aqua regia until a colorless solution results are about one-third as high as those obtained by the sulphuric-acid and potassium-nitrate method. Although the solution of the grain obtained by boiling with HCl and HNO_3 becomes practically colorless, organic matter is still present, as shown by the charred mass that results if it is boiled to dryness. The starch may be oxidized to some organic acid that resists oxidation and interferes with the precipitation of the phosphomolybdic precipitate.

Thanks are due to Dr. W. P. Kelley, who suggested this work on sulphur in rice plants, and to Dr. E. V. Wilcox and Mr. William McGeorge, who gave helpful suggestions throughout the work.

REPORT OF THE AGRONOMIST.

By C. K. McClelland.

COTTON.

The work in agronomy for the year has been along the same lines as in previous years, although the work with cotton has been given the most attention. This work with cotton was deemed of first importance because the culture of the crop is not yet upon a paying basis, and it was thought that an effort should be made to get all information possible in regard to the crop so that it would be possible to suggest the proper methods of management. Many of those who planted cotton within the past few years have been compelled to abandon it, owing to improper conditions of environment or to the ravages of the pink bollworm, which continues to be the principle insect destroyer of cotton.

During the year the agronomist visited the fields of cotton upon Kauai, and the assistant in agronomy visited those upon the leeward side of Hawaii. Also from time to time as opportunity offered, trips were made to the various fields situated upon Oahu.

A press bulletin upon Cultural Methods for Controlling the Cotton Bollworm[1] was published in the fall of 1911, showing what success was obtained in fighting the bollworm by the use of lantern traps, by pruning, and by clean culture. Later, another press bulletin[2] was issued giving general directions for growing the crop and giving a discussion of various varieties and practices, with such recommendations as could be derived from the study of the crop on Oahu and upon the other islands.

Briefly, these suggestions were to attempt to grow the crop only on lower elevations or at least in fully protected places; to grow Caravonica in extremely dry locations and Sea Island, if preferred, in moister situations, but that so long as the bollworm is present to grow it as an annual.

It will be sufficient here to add that because of the unusual extreme drought during the winter and spring months the prospects for the 1912 crop are far from promising. Some of the planters waited until late in the spring for rains which never came to do their pruning, and finally were compelled to go ahead without the benefit of rains to start the new growth. Under such conditions high pruning is advisable, but in some cases low pruning was resorted to, and the buds which started were not able to continue their growth but remained at a comparative standstill until into the month of June. Under other conditions where the work was done in the fall or where rains were more abundant in the spring the prospects are brighter and a medium crop at present is assured. With the prevailing low price for cotton and with a seemingly limited demand, together with the great damages still being worked by the bollworm, it would seem that prospects for cotton in general are not especially bright.

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[1] Hawaii Sta. Press Bul. 32.

[2] Hawaii Sta. Press Bul. 34.

Some samples of saw-ginned and roller-ginned Caravonica cotton were submitted to a New England firm which makes a specialty of carded cotton for woolen mills. The samples were run through the picking and carding machines and the shrinkage or waste was determined. The saw-ginned cotton suffered a loss of 9⅛ per cent and the roller-ginned only 7¼ per cent, which is about the same, the firm says, as is lost from Peruvian cotton. They consider the roller-ginned cotton, since it has about the same roughness as the Peruvian cotton, to be equal to it and allowed 18½ cents a pound for it, which was the price of Peruvian upon the market there at that time. For the saw-ginned cotton they allowed 18⅛ cents, or three-eighths cent less per pound.

At this price for cotton, not considering the cost of the roller gin, which costs double the amount that the saw gin costs, the excess of cost of ginning upon the roller gin greatly exceeds the extra amount which was received for the cotton; and if the price were greater the difference would be still greater in favor of the saw ginning. If the work is carefully done, then the profit is greater by using the saw gin, but if carelessly done and if the gin is run at too great a speed the damage may be greater than here reported, and the difference in price would be more.

This opinion, coming from a firm of recognized authority and who use cotton in large amounts annually, may be taken as settling the question of the use of the saw gin, which has been debated among the cotton growers of Hawaii. To one buying a gin, the difference is in favor of the saw gin, but to one already operating a roller gin the difference is not such as would justify an exchange of gins.

RICE.

The rice experiments have been continued as heretofore, and, although the rice-trial grounds will have to be given up at the end of this year, another small field will be obtained and the work continued. The introduction of the Japanese varieties among the Chinese growers progresses very slowly. The growers are loath to plant a rice for which they have in the past had to accept a lower price than they obtained for their other varieties. However, seed of two varieties was given to three growers in considerable quantities, and as these two varieties have been grown in Hawaii for several generations, an effort will now be made to give them a thorough culinary test and determine if possible what has been the effect upon them of the soil or climate.

In this connection it is interesting to note that in the Kapaa District of Kauai, a Japanese was found who claims to have been growing the Shinriki variety for the past nine years and that he finds it as good to-day as it was in the beginning. In the vicinity of Pearl Harbor, where this variety is grown on a large scale from seed obtained from the station, it is said that the Japanese are eager to obtain it and that the crop is rushed as soon as harvested to the mill and prepared at once for their use. From these two encouraging reports it would seem possible in time to grow a rice that will completely fill the requirements of the Japanese consumers.

SEED DISTRIBUTION.

During the year there has been quite a demand for seed of various kinds and it has not always been possible from our limited stock to fill all demands. Seeds of soy beans, pigeon peas, peanuts, broom corn, alfalfa, velvet and jack beans, various sorghums, and also roots of several prominent grasses have been sent out in answer to demands. Especially among the homesteaders has there been a great demand for these seeds.

DRY FARMING.

Some cooperative experiments were attempted upon a dry-land basis in a district out from Honolulu which is noted for its dryness, but no results have been obtained, for the reason that while heretofore in this region there has always been some rain during the year, for this once at least the rains failed entirely, and all the various crops tried have completely succumbed to the drought. The wind across this region is strong during most of the time and this, together with the lack of a percolating rain, caused the failures.

A small grass garden was started in the fall upon a very dry field located upon Magazine Street and a number of grasses and legumes were planted. Rescue grass and crimson clover were very promising at first but in the end probably the best showing was made by the Australian water grass. At present only this grass and some alfalfa seem to be alive, the others being dried up and withered by the extreme wind and drought prevalent there. Berseem and bur clover matured seeds, also rescue grass, but the majority of the grasses did not.

BROOM CORN.

The experimental work with broom corn has been continued upon a small scale. That planted in April, 1911, yielded at a rate of 311 to 658 pounds of brush per acre, the lower yield being obtained from the outer edge of the field near some algaroba trees which are far reaching in their influence. This brush was of excellent quality and was from 24 to 30 inches in length, which is longer than is desired by the broom manufacturers. Closer planting under the same conditions would have restricted the length. The crop occupied the land but 90 days and was sold for 6½ cents per pound.

The crop was allowed to ratoon and proved a failure, the yield being much less than at first, while the quality was very inferior, each stalk having coarse central stems in the brush. Perhaps better conditions of moisture would have produced a better result, but a ratoon crop under our dry summer conditions is inadvisable.

Another small area was planted December 20, 1911, from seed obtained in San Francisco. A period of dry weather followed with late winter rains. The brush obtained from this planting was of about the same quality as that obtained in the previous ratoon crop. This poor quality might be due either to the use of run-out seed, to the effect of the dry weather in the early stages of growth, or to the effect of the cool weather at the time of heading out. Some of this same seed was again planted April 4, 1912, and began heading out about the middle of June, the heads at this season being almost entirely free of the objectionable center stems. It would seem from this one experience that fall planting is undesirable; but another planting will be made to try and find out the exact cause of such poor quality.

From experiments thus far made it appears that there is a small profit only to be obtained in growing broom corn. As corn produces well in the winter months, it would be well to grow corn at this time and then to plant the broom corn after the corn in April or May. Where only small areas are grown and no machinery is used a good plan is to plant the broom corn in the rows between the corn, and especially if the corn is to come off late in the spring. In midsummer, provided there is sufficient moisture to start the seed, soy beans or other legume may in turn be planted between the rows of broom corn for green manure or other purposes. In this manner a return of about $30 per acre may be obtained for the use of the land for only about 90 days.

GRASSES AND FORAGE PLANTS.

The problem of grasses and legumes for hay, soiling crops, and pasture is very important, although for several years some attention to this subject has been given by the managers of the various ranches upon the different islands. The requirements are varied, and the conditions of environment are so greatly changed within short distances that it makes the problem even more difficult. The greatest demand of course is for suitable grasses for pasture, and for different ones that will be useful at different times. For winter months or for summer months; for wet districts or for dry; for districts with both a wet and a dry season; for low or for high elevations; for reasonably good and for poor rocky barren soils—these are the variations of environment for which it is difficult to obtain suitable crops.

From time to time upon the ranches a number of grasses have been introduced and tried out with the hope of finding a few which would answer requirements and thrive under the given conditions of environment. Although doubtless as many as 50 different species have been tried but few of them have been found that were especially valuable.

Another want is felt by the dairymen for a legume crop to grow in rotation with sorghum in the winter months for soiling. Alfalfa when once seeded is too valuable a crop for short rotations; soy beans have not produced desired amounts; the same was true for cowpeas, which were badly attacked by aphids; velvet beans and jack beans grew too slowly to give any satisfaction; and each crop tried seemed to be lacking in some important point.

For hay there is a considerable demand only in the larger towns and also by the Government for the Army horses and mules. Considerable quantities of Ajax wheat hay are brought in from California. Upon the plantations cane tops furnished the greater part of the roughage in the rations. Some alfalfa is imported and there is a small amount grown and cured here. Pará grass and Guinea grass are used to some extent, but these, like alfalfa, are more often used as soiling grasses and fed when freshly cut. Rhodes grass and Natal redtop have been recommended for hay crops under various conditions, the former being especially drought resistant.

In order to glean what lessons have been learned by these various experimenters and to be able to give their experience to others interested, it is the intention to make a careful study of these trials upon the different ranches from time to time as opportunity offers, and already some important lessons have been derived from a study of the methods used in improving pastures and conditions in general upon the Princeville plantation near Hanalei, Kauai.

RANGE IMPROVEMENT.

The ranch known as Princeville plantation consists of about 12,000 acres in the Hanalei district of Kauai varying in elevation from sea level to 1,000 feet above. On the lower lands are now some 700 acres in rice while the upper lands, several thousand acres in extent, are precipitous and covered with forest. The pasture lands lie mostly between 300 and 800 feet in elevation and are cut up here and there by several deep gulches. In places these gulches are very wide and formerly were swampy and many animals were lost in them. There was also a considerable loss in the high lands from cattle falling over the bluffs or from the narrow trails along the gulches.

The pasture lands were covered with a heavy growth of lantana and of guava, averaging from 15 to 18 feet in height. To subdue these shrubs, buffalo grass (*Stenotaphrum secundatum*) was introduced in 1902, 100 acres being planted, and from then until 1908 about 900 acres more were planted with this grass.

In 1905, Mr. W. F. Sanborn, the present manager, was placed in charge and a more scientific and practical effort made to achieve good results. From the practical point of view it was reasoned (1) that land covered with guava and lantana, neither of which were of value as forage, could carry only a small fraction of as many cattle as it could if these shrubs were destroyed; (2) that if the innutritious and unpalatable grasses, such as Hilo grass and other native grasses, were supplanted by better ones, this would also help to increase the carrying capacity of the pastures; (3) that if the quality of the cattle were improved by using pure-bred sires from some credited beef breed, within a few years it would be possible to produce a pound of beef upon much less feed than was required to produce that amount in scrub cattle; and (4) that by draining the swamps and by fencing off the cattle from the bluffs and precipices, losses from such sources would be eliminated.

Experiments were undertaken in a scientific manner to determine what grasses would thrive under the given conditions, what were the best methods and times of seeding, and finally out of those grasses which thrived to select those which would stand grazing and would not be crowded out by native or less valuable grasses when grazed by the cattle. To determine this more than 30 different grasses and legumes were planted in small plats in three different locations under slightly different conditions. The results to date are not conclusive, but indicate roughly what is to be expected from many of these under the given conditions.

Since 1905, about 3,000 acres have been cleared of guava and lantana. After grubbing these out the land was plowed shallowly with sod plows. After such time as was necessary for the rotting of the roots the land was harrowed, then cross plowed more deeply than at first, and later still another harrowing, plowing, and another harrowing were given. Although moisture conditions were often favorable for spring planting yet it was learned that because of attacks of cutworms, it was always expedient to plant in the autumn; also that to cover the seed with a smoothing harrow very often resulted in failure, as the young plants were likely to die out if dry weather followed soon after the seed germinated. A better plan was to harrow with a heavy spike-tooth harrow, leaving the surface in small ridges, over which the seed was then broadcasted, allowing the rains to cover the seed. By this method it was observed that even if the plants upon the ridges died out, those in the little furrows between, having the benefit of more moisture and greater protection from wind, usually survived and insured a stand.

The rainfall varies greatly in this district. It may be as low as 30 inches at some points along the coast and it may be as high as 200 inches in some years at the highest points of the hills, probably 60 inches is a fair average for the greater part of the land where the seeding has been done. It will be seen from this that conditions for growth of grasses are much better than could be found on the leeward side of any of the islands.

In addition to the 1,000 acres of buffalo grass above mentioned there were planted in the beginning about 4 acres of Para grass, 20 acres of Guinea grass, and a small area in alfalfa from which fields hay is now obtained for the mules and horses.

There were planted in 1909, 40 acres of *Paspalum dilatatum* and also 350 acres of *Agrostis vulgaris*, or redtop, and *Dactylis glomerata*, or orchard grass; in 1910, 500 acres of *P. dilatatum;* in 1911, 400 acres of *P. dilatatum* and of orchard grass mixed, using, per acre, 10 pounds of orchard grass to 5 of the Paspalum; also in 1911 about 30 acres were seeded to *P. virgatum* and *P. compressum.* This year, 1912, 400 acres will be planted to *P. dilatatum* and *P. virgatum* and Natal redtop, using 10, 3, and 2 pounds per acre, respectively.

This makes a total of about 2,700 acres which will have been seeded to tame grasses for pasture. Hereafter about 200 acres will be seeded annually until all arable land is planted, after which some of the buffalo grass will probably be replaced.

The fields are now divided into 10 paddocks and the cattle into 6 herds, which allows a period of recovery in each paddock by occasionally changing the herds to fresh pastures. The swamps have been drained and the cattle fenced from the rougher mountain lands, and in addition to the saving of losses from these sources it has been noticed that the cattle suffer less from the liver fluke than before the drainage was done. The loss of calves in 1912 was only 0.3 per cent, all of which occurred in animals under 6 weeks of age. The herd has been increased from 900 head in 1905 to 2,000, and it is evident from the looks of the pastures that a further increase of at least 75 per cent would not damage them. There are now 19 pure-bred Hereford bulls and 10 heifers of different ages, some of which were imported from Missouri, Iowa, California, Washington, and from New Zealand. This number is sufficient to furnish a home supply for breeding purposes for several years. The original stock, which dresses 400 to 500 pounds at 5 or 6 years of age, is gradually being replaced by half-breed Herefords, and it is hoped that within a few years they will be able to sell animals dressing twice as much at one-half the age.

NOTES UPON VARIOUS GRASSES.

(1) It was noticed upon the newly seeded lands that the ground was first covered with kukaipua (*Syntherisma sanguinalis*), white honohono, and so-called glue bush. These annuals, the first two of which make good grazing, shade the land and protect the tame grasses from the sun and wind, thus giving them a better chance to grow. When the latter have attained some size, nothing more is seen of the former.

(2) In planting orchard grass with paspalum the former seems to grow more rapidly at first and furnish grazing much sooner than the latter, and it is more valued because of this habit.

(3) Natal redtop seems to be better for hay than for grazing, but has some value for pasture when mixed with other grasses.

(4) *Paspalum dilatatum*, *P. virgatum*, and *P. compressum* each seem to have the power to crowd out Hilo grass (*P. conjugatum*). All of them are very promising as pasture grasses and are spreading over the adjoining fields. Which of them will be the most persistent is yet to be determined.

(5) It was observed when trying to start *P. dilatatum* from roots placed in the open fields that the cattle ate it greedily, pulling it up or pawing it out before it had time to get well rooted. However, when a plat containing several finer grasses was thrown open for pasture they grazed the latter as closely as a lawn is clipped. but allowed the coarser paspalums to attain greater size.

(6) Orchard grass, creeping bent, Rhode Island bent, Kentucky blue grass, Italian rye grass, Natal redtop, *Paspalum floridum*, and other grasses which seemed to start well are very likely to be crowded out by the coarser paspalums because of this close grazing by the cattle and because of the greater vigor of the latter.

(7) Rescue grass, velvet grass, and a mesquite grass were crowded out by other grasses. Rescue did especially well in the plats at first.

(8) White clover was completely eaten up or rooted out by the cattle.

In view of the fact that in the United States all of the old cattle ranches are being transformed into smaller farms and given over to the production of field crops as well as the raising of cattle, and that the feeding of the cattle upon these farms will in the future be a more important work than the grazing of them, it is perhaps to be wondered why at this time an owner would think of seeding down a ranch to grass and planning to raise cattle by grazing only. It is true that in Hawaii some of the ranches have followed the lead of those in the United States and have given up the cattle business and devoted the land to the culture of crops, either cane or pineapples, and that is proper since with these crops there is an assurance of greater returns per acre than with cattle; but at Hanalei there is such a heavy rainfall that a good growth of grass is at all times insured, so that with good stands of palatable tame grasses the carrying capacity of an acre is much larger than would obtain upon lands on the leeward sides of the islands or in the regions in the United States which were in the past devoted to the cattle ranches. Furthermore, a market for the beef is assured right at home upon the island of Kauai, and as such supply is necessary it is fitting that the supply of the need should be undertaken in a scientific and businesslike manner, which, it would seem from this study of methods, has been done.

Upon rougher and rocky lands such a practice would be out of the question and methods used under these conditions would be more laborious, expensive, and in the end would result in stands less perfect than is possible by the method described; and the carrying capacity of an acre could never equal that in the case given. However, the best method in which to work over rocky and rough lands is worthy of study and may be reported upon later.

REPORT OF THE SUPERINTENDENT OF THE HAWAII SUBSTATIONS.

By F. A. Clowes.

HILO SUBSTATION.

The Hilo substation comprises approximately 1¾ acres of land bordering on the farm of the Hilo Boarding School. The use of this land was granted to the experiment station by the Territorial government in December of 1910. The experiment station entered into a cooperative agreement with the Hilo Boarding School, whereby the school supplied all the unskilled labor, mules, and farm machinery for the plats and the experiment station directed the work. This arrangement has been very satisfactory and valuable work has been accomplished.

Three lines of work have been carried on, namely, experimental work with upland taro, experiments with bananas, and demonstrations of leguminous crops for feeding and green manuring.

Two taro experiments were planted and harvested during the period under report. The first was one to determine the relative value for seed of the three classes of seed or hule, namely the makua or parent hule, the oha or hule from the large lateral corms, and the puu or the small lateral hules planted entire. The other taro experiment was a fertilizer test. These two experiments covered an area of three-fourths of an acre. (The results will be published later in bulletin form.)

A plat 120 by 135 feet is devoted to a test of planting Bluefields and Hamakua bananas at distances apart of 8 by 8 feet, 10 by 10 feet, 12 by 12 feet, and 15 by 15 feet. At the time of planting there was uncertainty as to identification of the Bluefields and the Hamakua bananas. These two varieties are so similar that it was impossible to get a clear and distinctive description of each. It was the intention to plant the experiment with the Bluefields, but it was impossible to secure a sufficient number of plants that were genuine Bluefields. Sufficient Bluefields were secured, however, to plant one row across each plat of the experiment, and a sufficient number of the Hamakuas to plant another row across each plat of the experiment were secured. All the other plants used were of a mixed lot which at the time could not be separated into Hamakua and Bluefields.

At the time of planting it was noticed that the Hamakua suckers were of a deep purplish red color at the base, while the Bluefields were of a lighter pink color. This was found to be a constant difference between the suckers of the two varieties. The Hamakua always tends to have a dark red color on the stalk below the ground, while the Bluefields is of a light pink color. Another readily noticeable difference is that the midrib of the Hamakua leaf is green, with little if any tendency to pink color, while the Bluefields has a decided pink or red color to the midrib. This difference is particularly noticeable in the suckers of the two varieties. Moreover, the Bluefields are about 1 foot taller.

The bananas in this experiment, having been planted in June, 1911, are not yet matured. The results are, therefore, not yet available.

Small plats of soy beans, cowpeas, pigeon peas, jack beans, velvet beans, and alfalfa are grown in order to demonstrate to stock raisers of the surrounding region the crops which could be profitably grown to supplant grain in cattle rations.

GLENWOOD SUBSTATION.

The Glenwood Experiment Farm (Olaa substation), consists of 16½ acres of land situated on the Volcano Road at Glenwood. The elevation above the sea is 2,300 feet. The land has a good slope to the southeast. The soil is deep and with the exception of a small area has good natural drainage. The buildings, which were erected previous to July 1, 1911, are a superintendent's cottage, and a farm building containing office, storeroom, workroom, men's dormitory, horse stable, implement shed, and tool rooms. There have since been added to this equipment a cow stable to accommodate four cows, and a building 14 by 18 feet for dairy purposes. The equipment for this is now ordered, and consists of a 3-horsepower steam boiler, a 1-horsepower steam engine, turbine Babcock tester, combined churn and butter worker, and the necessary utensils and accessories for the production of first-grade farm creamery butter. A power separator has been donated by Mr. B. F. Dillingham.

Tributary to this experiment farm is a large area of apparently good land, much of which is public property available for homesteading purposes. A considerable area of privately owned land has been cleared of the heavy growth of ohia forest that originally covered it. At one time there were extensive coffee plantations laid out here, but after the first crop further profitable crops were not obtained. Following the coffee, much of the land was planted to sugar cane. The results with this crop have almost uniformly been that only first cuttings were profitable, the ratoons almost always proving financial failures. Tobacco was at one time successfully grown, but the settlers who raised it were unable to secure a market, and had to give up their homesteads and seek a living elsewhere. At present much of the cleared land is under lease to ranchers and is affording pasture for range animals. A promising butter business has survived the agricultural misfortune of this region and one grower is raising easter lilies and pohas (*Physalis peruviana*) with fair success.

There are evidences of extensive agricultural work in this region in the days of abounding native population. The native bananas (mauli type) are found growing in extensive plantations, olena (*Curcuma longa*), mamake (*Pepturus albidus*), loulu (*Pritchardia gaudichaudii*), taro, and sweet potatoes are among the plants found growing in what would otherwise seem to be primeval forest, but in reality bears clear evidence of extensive prehistoric agriculture.

The rainfall in this region is in the neighborhood of 200 inches a year. The elevation is such that there are comparatively few days without a fall of rain. This makes field work disagreeable and renders the soil sticky. Unless great care is exercised, attempts to carry on horse cultivation serve only to puddle the soil and to produce a hardpan that is impervious to water. The tramping of the cattle in the pastures renders the surface so impervious to water that except in dry weather the surface soil is always in a condition of saturation. The soil temperatures are low, and on account of the elevation the air is cool. Plant growth is very slow. Cutworms and slugs are abundant, and the prevention of their ravages constitutes one of the big problems of the region. The moist conditions favor the presence of plant diseases. The saturation of the soil with water precludes oxidation, and the seepage of soluble plant food renders the soil lacking in plant food in quantities that would produce the most profitable crops without frequent application of fertilizers. The lack of air and the unoxidized and poisonous nature of the subsoil retards the downward progress of roots. Hence what would, from its friability and freedom from stones, seem to be a very deep soil is in reality a very shallow one.

This brief description will serve to illustrate the practical problems for the solution of which the Glenwood Experiment Farm was established.

The dairy business in this region depends at present upon extensive cheap pasture and an abundance of wild honohono (*Commelina nudiflora*) for soiling purposes. It does not rest upon a permanent foundation. Cattle thrive in this region, and the country seems to be adaptable to the live-stock industry. It has seemed wise, therefore, to devote considerable effort toward establishing the permanence of the dairy and live-stock industries. Much space and time are given to experiments on fodder crops. It is also intended to operate a small farm creamery for experimental and educational purposes, in the hope of establishing the market end of the business upon a firm basis.

Besides the dairy work in its two branches, experiments are in progress with a great variety of market crops. A study is also being made of methods of cultivation, soil treatment, and drainage. Fertilizers are also being tried out with the aim of determining the requirements of the various crops upon these soils. A demonstration and experimental wood lot is also being planted.

Much of the time during the past year has been devoted to the rough work of removing stumps and otherwise preparing the land for systematic experimenting. Small plantings have been made of various crops at all months of the year with the idea of studying the effect of unseasonable plantings and also to find crops which gave sufficient promise to justify larger plantings. In the further development of these trials there have been planted the following forage crops:

Para grass, one-half acre; Japanese cane, one-half acre; honohono or commelina, one-half acre; corn and sorghums, 1½ acres; (of these 40 varieties are under trial); dwarf Essex rape, one-fourth acre. In addition the following have been planted: Broom corn, one-fourth acre; sugar cane for milling, one-half acre (four varieties); and pohas or ground cherries, one-fourth acre. These last grow wild in this region and the fruit sells readily as a canning crop. It is desired to determine if they can be cultivated profitably. There is also about a quarter of an acre devoted to variety and fertilizer tests on vegetables and flowers. Of these the following have given results which are believed to warrant the planting of larger areas: Cabbages, cauliflower, strawberries, Easter lilies, cucumbers, pole beans, rutabagas, and kohl-rabi.

Preparations have been made to plant about a quarter of an acre of cooking bananas.

Other crops which have given promise as forage are field peas and oats. It is intended to plant these on a larger scale. Small trials are being made of grasses (20 varieties), clovers (11 kinds), vetches, oats, flax, buckwheat, spelt, emmer, wheat, millet, peppermint, ginger, *Canna edulis*, awa, asparagus, potatoes, sweet potatoes, and bananas (8 varieties).

In the woodlot plantings of all the trees commonly grown for such purposes throughout the Territory have been made. Others will be tried later.

Other trees and shrubs planted are apples, walnuts, camphor, Chinese oil-nut tree, rose apple, and mammee apple.

The fertilizer work is incomplete. Enough, however, has been accomplished to show that even on new land fertilizer gives decided beneficial results. Stable manure has given better results than applications of complete high-grade commercial fertilizer. On abandoned cane land that had been used for pasture for several years 500 pounds of complete high-grade fertilizer was needed to produce even a fair crop of corn. It is evident that heavy fertilization is needed, and apparently this should be applied as often as once every three months.

Acknowledgment is made of the many kindnesses of the business men of Hilo, the officials of the Olaa Sugar Co., and many others who have shown interest and given much help in the work of equipping and establishing this substation.

REPORT OF THE SUPERINTENDENT OF THE RUBBER SUBSTATION.

By W. A. Anderson.

TAPPING CEARA RUBBER.

The Ceara tapping on the Nahiku plantations has been directed chiefly toward the development of a system of tapping that would yield the largest amount of rubber per unit of labor without injury to the tree, and curing the product in such a way as to make it satisfactory to the manufacturers.

Many methods which would give profitable results in most tropical countries with their cheap labor, were found to be impracticable here with labor at approximately $1 per day. No satisfactory incision method for tapping the Ceara tree without removing the outer bark has so far been found. At the same time, aside from the expense involved, the injury which results from the frequent stripping of the entire outer bark makes this undesirable.

In July, 1911, after a considerable amount of experimenting, tapping on a commercial scale was started by removing the bark to a height of about 18 inches and pricking with a wheel pricker making pointlike incisions, run vertically, on four sides of the tree at each tapping. The latex was allowed to run to the ground and left there until the following day when it was coagulated. The rubber was then collected, in a very dirty state, washed with a single macerator, vacuum dried, hung in the air for one to two weeks, and then shipped. The average yield per day's labor involved in preparing the trees, removing the bark, tapping, and collecting, on 5-year-old trees, on 70 acres, in two months, was approximately 2 pounds of washed rubber. It was found that after two weeks of tapping daily, the yield fell off to such an extent as to indicate the suspension of tapping.

On trying to resume operations after a rest of two weeks, it was found that the flow of latex was hindered by the new outer bark, that was forming a scaly, powdery covering which gradually became thicker and tougher, preventing the flow so that this form of incision could no longer be profitably made without stripping the bark again. Experiments in removing the bark on the 18 inches next higher up showed that too little latex reached the ground and that which remained on the tree could not be readily collected. Jabbing with a flat knife blade, making a horizontal incision on this newly stripped area, gave a better flow of latex, but the expense of collecting proved this impracticable, both with and without a previous application of acetic acid.

These experiments, however, demonstrated two fundamental facts: First, that a knife jab made horizontally gives better results than one made vertically; second, that the portion of the tree just above the ground, to a height of about 6 inches, yields rubber in much larger quantities than any other portion. This area is never tapped when collecting cups are used, as the spout is necessarily inserted high enough to conduct the latex to the cup, set on the ground, and the tapped area is all above the spout, and, consequently, above the most prolific section of the tree.

The second of these facts was utilized in the development of a system which has undoubtedly given better results in proportion to the labor involved than any other. By this method, the bark is removed to a height of about 6 inches and cuts made with a very thin knife blade from the ground to the top of this stripped surface. The latex is allowed to flow to the ground and coagulate. The following day the rubber is collected and new cuts made at the same time.

The advantages are obvious. Only the richest portion of the tree is utilized, and at the same time, the portion where injuries heal most quickly After the first cutting, the collecting and cutting are performed at the same time, thus saving one-half of the walking that would be necessary in passing from one tree to another if there were separate operations. The cutting knife is used to facilitate the removal of the rubber from the soil in collecting, so that there is no time lost in changing tools. The laborer carries his bucket in one hand and his knife in the other, sets the bucket down, naturally nearest the hand that is freed, slips the knife under the lump of coagulated rubber, on the ground, lifts the rubber with the free hand, aided by the knife, deposits it in the bucket, and makes his new cut in the tree with the knife in the other hand, lifts the bucket with the free hand and passes on. It would seem that the number of motions involved is reduced to a minimum. The largest amount of rubber collected in this way, by one man in one day of 10 hours' tapping and collecting, is 9 pounds of washed rubber, though the average yield for 100 acres during six months' tapping is somewhat less than 4 pounds.

The disadvantages lie chiefly in the fact that so small a portion of the tree is tapped. The yield per tree at each tapping is small, in some cases 1 pound of washed rubber to 400 trees. The number of tappings possible per year, as indicated by a six months' trial, is about 48, with two strippings per year. The removal of bark appears to be less injurious on this area than higher up, and it is probable that the trees would stand this removal. Each stripping after the first is more difficult, as the cuts make the renewed bark very rough and it breaks off in small patches instead of coming off as one sheet, as is the case with the first stripping. If the cut is made properly it heals without a ridge and more quickly here than elsewhere on the tree. Attempts to continue this method higher up on the tree have not so far proven successful.

Having thus found approximately the maximum yield per day's work, attention was directed toward increasing the yield per tree, with a view to getting a proper adjustment between these two, which will be the point of diminishing returns. As satisfactory results were not obtained by continuing to remove the bark in horizontal strips, vertical strips were tried. First, a strip about one-third inch wide was removed with a broad, U-shaped knife, gauged to remove only the outer bark, exposing the inner bark for incision. The incisions were made with a blade of the same width as the stripped surface, at regular intervals, along the length of the strip. In this way the yield per tree per tapping was increased, but too large a portion of the rubber remained on the tree as scrap, which could not be profitably collected. The application of a solution of acetic acid caused practically all the latex to coagulate on the tree, where it was collected to better advantage. To widen the stripped surface, a second cut was made 1 inch or more from the first, and the bark between these two cuts was removed. This is done quickly and simply. The wider strip is treated with acetic acid and incisions made at intervals of about 2 inches, with a blade 1 inch wide, so sharpened as to touch the cambium at only two points instead of along the entire edge. The rubber is collected one hour after tapping.

The experiment is not yet completed, only one week's tapping having been done. It is found, however, that one man can make the incisions as fast as two men can collect, and the three men in one day can incise and collect from about 800 trees exclusive of stripping, securing about 1 pound of washed rubber to 70 trees. Four tappings can be made on each strip before exposing a new surface. Including stripping and all labor, results for the week were at the rate of 2⅔ pounds per day's work.

For the purpose of comparing this method with the one previously described, which gave the maximum yield per day's work, we may call the former method A and this one B. Calling the average yield per day's work in A 4 pounds, and the average yield per tree one three-hundredths pound, we get 4 pounds from 1,200 trees in one day's work. In B we get 2⅔ pounds from 186 trees in one day's work. It is obvious that were the number of trees available unlimited, A would be the better method. Since on any plantation, however, the number of trees is necessarily limited, the total profit on labor from a given number of trees will determine the relative value of the two methods. From 50,000 trees A would give 167 pounds in 41⅔ days' work. At $1 per day and $1 per pound (the approximate present values), profit on labor would be $125.33. B would give 683.4 pounds for 268.8 days' work, leaving a profit on labor of $414.60 from the same number of trees, from which it appears that B is the more profitable plantation method so long at least as the value per pound of rubber remains greater than one-half the cost of a day's work.

This tapping was done in the last week of June. It is probable that better results can be obtained during the latter half of the year, as the trees are not in full leaf before the middle of July.

CURING AND MARKETING CEARA RUBBER.

The rubber obtained was shipped direct to manufacturers in New York. The first shipment, vacuum dried, was valued at 10 per cent below the best Para and sold on that basis. Two later shipments, treated like the first in every way, but not vacuum dried, were valued over 25 per cent below Plantation Pale Crepe. While the last shipment from which returns have been made, partly vacuum dried, was sold at 10 per cent below Ceylon Fine Pale Crepe, and brought $1.15 per pound. The rubber is now all being vacuum dried and pressed while still warm from the dryer into sheets about 2 inches thick, 10 inches wide, and 3 feet long, weighing approximately 20 pounds each. The loss in washing and drying rubber thus prepared has been found to be 2⅕ per cent.

The conclusions from the work so far done are that tapping method A is the cheapest and most desirable where the trees to be tapped would furnish work for all the labor available, but method B gives greater profit from a given number of trees, and that either method can be carried on commercially at a profit under present conditions. The product, though very unattractive as it comes from the field, is capable of being turned into rubber of the first class without too great expense.

Contemplated experiments on a commercial scale to determine the effect of fertilizers on the yield of latex have not been carried out, but it is hoped that some work of this sort can be done in 1912.

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Issued March 16, 1914.

HAWAII AGRICULTURAL EXPERIMENT STATION,
E. V. WILCOX, Special Agent in Charge.

ANNUAL REPORT

OF THE

HAWAII AGRICULTURAL EXPERIMENT STATION

FOR

1913.

UNDER THE SUPERVISION OF
OFFICE OF EXPERIMENT STATIONS,
U. S. DEPARTMENT OF AGRICULTURE.

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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LETTER OF TRANSMITTAL.

Hawaii Agricultural Experiment Station,
Honolulu, Hawaii, July 25, 1913.

Sir: I have the honor to transmit herewith and to recommend for publication the annual report of the Hawaii Agricultural Experiment Station for the fiscal year ended June 30, 1913.

Respectfully,

E. V. Wilcox,
Special Agent in Charge.

Dr. A. C. True,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. True, *Director.*

Publication authorized.
D. F. Houston,
Secretary of Agriculture.

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ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1913.

SUMMARY OF INVESTIGATIONS.

By E. V. Wilcox, *Special Agent in Charge.*

DEMONSTRATION FARMS.

The continued support furnished to this station by the appropriation of funds by the Territorial Legislature has made possible the prosecution of various practical demonstrations and experiments at six substations located at Glenwood, Hilo, Hana, Waipio, Homestead, and Waiakoa. At the recent session of the Territorial Legislature the yearly appropriation was increased from $10,000 to $15,000 for the purpose of carrying on the work at these demonstration farms and others to be established, as well as assisting in a cooperative scheme of marketing island products. The additional substations for which plans have already been made are to be located at Kaupo, Kapaa, Laupahoehoe, Waimea, and in Kona.

With the exception of the substations at Glenwood and Hilo, the basis of operations on the substations or demonstration farms is of a cooperative nature. The funds supplied for the purpose of carrying on substation work are quite inadequate to put up buildings, buy horses, mules, machinery, and other equipment, and hire labor for such work as would be necessary on the areas in question. As already indicated, the only substations on which this method of procedure has been adopted are the Glenwood and Hilo substations, particularly Glenwood, where especially discouraging conditions of agriculture existed and where large areas of valuable land were available for homesteading. On all the other substations the plan has been essentially to offer a small subsidy to the man who was considered best fitted to carry on the work in each community.

The choice of the superintendent of the substation has in all cases been reached in conference with the various members of each community. A plan for certain practical experiments and demonstrations is then prepared by the station and this plan is carried out on the homestead owned by the superintendent. No experiments involving unnecessary expense to the superintendent are undertaken, and all produce raised on the homestead belongs to him. The subsidy which has been offered to encourage the work has been in each case merely sufficient to compensate the superintendent for the extra time involved in keeping records of the yields, cost of production, and on other points on which it is necessary to have definite information. The practical benefits from this method of carrying on demonstration work have been even greater than was to be expected, without considering the extreme economy of this method of procedure.

Taking as an illustration the community at Homestead, Kauai, where at the time of the establishment of the substation a large Portuguese community was struggling under debt and under a discouraging uncertainty as to what could be profitably planted, or what cultural methods to adopt for such crops as they might wish to try, it is easy to obtain convincing proof of the value and economy of the substation work by making a visit to this community at the present time. The results obtained by the superintendent of the substation under the direction of this station have led to the adoption of improved methods throughout the whole community, which in turn have resulted in little less than a revolution in the farming methods of the community. By adopting the methods recommended by the station the superintendent of the Homestead substation produced this year a yield of 24 tons of pineapples per acre, which is far in excess of the average yield of this fruit. In addition to pineapples, methods have been adopted for the profitable production of corn, potatoes, sweet potatoes, cabbage, and a number of other vegetables. These results have been obtained by the expenditure of $300 annually on the part of the station. The members of the Portuguese community in question three years ago were all deeply in debt, while at present a considerable proportion are entirely out of debt and the remainder probably will be within the next two or three years. Not only have the financial benefits to the community as a whole been quite out of proportion to the small sum expended for demonstration work, but the spirit of the community has become correspondingly more optimistic and a far greater intellectual interest is now taken in the business of farming.

A further advantage of this method of carrying on demonstration work under Hawaiian conditions lies in the fact that the produce of the demonstration farm belongs to the homesteader and not to the station. There is almost always a feeling of resentment at what small producers consider the injustice of a Government institution producing farm crops which must be sold in competition with their own produce. This annoying cause of friction is avoided by the method just outlined, and the results of improved methods which are so obvious on the demonstration farm are clearly understood by all members of the community to be obtained not by a Government institution with the finances of the Government back of it, but by an ordinary farmer using economical methods which can be adopted by every member of the community.

At the Glenwood substation the work of the year was continued along the same lines as have been previously described. Attention was chiefly devoted to putting the dairy industry of that section of Hawaii on a profitable basis. At the substation a small modern creamery plant was established and the milk supplied by a few dairymen who were interested in the experiment was received, skimmed, and the butter churned. This work was undertaken with the distinct understanding that as soon as a sufficient number of dairymen were convinced of the desirability of forming a cooperative creamery they should form such an association and take over the business of making the butter of the community. Starting with an output of 500 pounds of butter per month, the creamery soon worked up to the production of 2,000 pounds monthly, at which time the Glenwood Creamery Co. was organized on a strictly cooperative basis, for the purpose of making and handling the butter of all the dairymen in that section of Hawaii. The work of the Glenwood substation from now on will be largely along the lines of improving the dairy stock of the neighborhood, learning and demonstrating better methods of forage production, developing improved cultural methods for garden vegetables and flowers, and assisting in any other agricultural industry which gives promise of profit to the homesteaders of Glenwood.

At the Hilo substation attention has been given to various points in the cultivation of bananas and taro. While these experiments have not yet been brought to a final conclusion, it is apparent that the results will be sufficiently interesting to warrant a separate publication in the near future.

At the rubber substation experiments have been carried on with a great variety of tapping methods for Ceara rubber. Some of these methods have recently been outlined[1] and need not be repeated in this connection. It is sufficient to say that a method for tapping Ceara rubber has been devised by which rubber can be obtained for a smaller cost of production than has heretofore been found possible with this kind of rubber. Arsenite of soda has been generally used again this year over the whole area devoted to rubber and appears to be the only efficient method of destroying weeds in this section. No injurious effects have been observed from its use. The only additional treatment that seems necessary in preserving satisfactory soil conditions is dynamiting. Preliminary experiments indicate that by dynamiting the soil between rubber trees and spraying with arsenite of soda excellent drainage conditions can be maintained and the weeds can be held strictly in check. The fertilizer experiments which have thus far been carried on with rubber, while indicating certain conclusions regarding the proper fertilizer to use for Ceara rubber, are thought to rest on the use of too small an area of ground to give results of reliable certainty. Plans have already been made, therefore, to carry on a fertilizer test on 4 acres of uniform trees for the coming season of tapping. From this experiment it is likely that definite conclusions can be drawn as to the influence of various fertilizers upon the flow of latex and the growth of the trees. In addition to work with rubber, a number of experiments have been carried on with intercrops between the rubber trees. Corn, sweet potatoes, broom corn, and roselle have yielded profitable returns, and all such cultivation between rubber trees has the added advantage of keeping the soil in better tilth and thereby hastening the growth of the trees.

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[1] Hawaii Sta. Press Bul. 44.

The excessive drought which prevailed at the Waipio substation during the past year was the cause of a very unsatisfactory growth in nearly all the crops with which experiments were made. While the conditions of the past year were unusually unfavorable it was thought best to devote a larger portion of the substation to pineapples, particularly since with the extension of the pineapple industry better facilities are offered for disposing of this crop than for most crops in the Waipio neighborhood.

At the Waiakoa substation a start has been made toward determining whether it is possible to control the potato blight, which has ruined the potato crop of this section nearly every year for the past 30 years or more. Here, as at Waipio, the excessive drought rendered the experiments of the first season somewhat doubtful, and the experiments will have to be repeated under more favorable conditions. It is apparent, however, that whether or not an economical method can be developed for controlling the blight of potatoes, great improvement can be brought about in the method of corn cultivation which prevails over the several thousand acres of this district.

COOPERATIVE MARKETING.

The Territorial Legislature, at its last session, specified that the funds allotted to this station to assist in its work should be devoted to the further development of demonstration farms in various parts of the Territory and to the devising of better means for marketing farm produce. In order that this may be accomplished more satisfactorily it seems necessary to devise a general scheme of cooperative organizations for farmers in various parts of the Territory, with the idea of ultimately bringing about an affiliation between all of the cooperative associations, with a central office in Honolulu to promote the proper marketing and distribution of farm products. With this end in view a beginning has been made, with the result that six cooperative associations of farmers have already been formed. This list includes the Glenwood Creamery Co., the Hawaii Poultry Association, the Homestead Farmers' Association, Kapaa Farmers' Association, Haiku Farmers' Association, and Waimea Farmers' Association. Pursuant to joint resolution No. 1 of the 1909 session of the Legislature of Hawaii, the special agent of this station was appointed chairman of the Fruit Growing and Truck Farming Commission, to draw up plans for the improvement of marketing conditions among the farmers of Hawaii. The report on this subject was published in 1910, the principal features of which have served for further work along the same line. At present there seems to be no method by which the farmers can economically market their crops in the Territory except by the formation of cooperative associations. In no other way can a uniform supply of produce be furnished to any particular market. Without a uniform and constant supply it is impossible to build up and hold a trade. Unless a supply of any given product is shipped regularly to the Honolulu market the dealers refuse to handle island produce, and make definite arrangements for regular shipments by boats from San Francisco. The practical results shown in the rapid development of the market for local butter and buttermilk from the Glenwood Creamery Co. show clearly how effectively this plan obviates the great disadvantages under which the farmer must labor if he operates independently. Not only is he unable independently to maintain a uniform supply and hold his trade, but he is under the disadvantage of having to pay a higher freight rate for small shipments than is the case where associations are formed among all members of a community who are occupied in producing the same crop or product. The formation of cooperative associations has already shown great benefits, and has fully justified itself from the social and intellectual side alone, without reference to the business aspect of the matter. The frequent regular meetings of the members of the community bring about a free interchange of ideas as to the kind of crop to be raised, the methods of culture, and all other matters concerned with the production and marketing of crops. The social activities of such gatherings bind the communities together more closely than could be accomplished by other means. It is possible to secure a more complete set of agricultural publications for a community library than could be obtained by any one individual. All the business, social, and intellectual interests of the community, therefore, center naturally about the cooperative association.

It is obviously impossible for the station to actually handle produce for farmers in the manner of commission merchants or dealers. Even if this were possible it would merely place an additional link in the already too long chain of middlemen between the producer and the consumer. It is a very simple matter, on the other hand, for the station to keep various cooperative associations informed as to the state of the market in Honolulu by means of brief market statements showing what kind of produce is needed, the quantities, the preferred method of packing, and the difficulties and losses incurred from improper methods of packing and shipping. The secretaries of cooperative associations can in turn keep the station informed as to the conditions of the crops in each community, the amount of produce which is nearly ready for market, and in this way the station can act, with very little expense, in addition to its ordinary work, as an effective means of bringing the producer and consumer together. It is believed that within a period of two years the workings of the cooperative association will become familiar to the majority of farmers with benefits so obvious as to bring about a complete affiliation of the different associations, at which time the farmers can maintain at their own expense, and with profit, a market bureau in Honolulu for handling and disposing of their crops.

ENTOMOLOGICAL INVESTIGATIONS.

Advantage was taken of an opportunity offered by a special expedition to Laysan Island to accompany the party and make a study of insect conditions on the island. The entomologist obtained a rather complete collection of the insects of Laysan, some of which proved to be new and have been described, while other biological observations with reference to the peculiar flora and fauna of Laysan were made.

In connection with a series of experiments to determine the possibility of artificial fertilization of queen bees a thorough study was made of the biology of bees in Hawaii. It is still uncertain whether a satisfactory method of artificial fertilization can be put on a practical basis, but a bulletin on the subject of bee keeping in Hawaii has been prepared. Studies were also made of the insect pests of tobacco and vegetables, with special reference to the life history of these insects, their parasites, and artificial methods of control. The entomologist has spent a considerable portion of his time, by cooperative arrangement with the Bureau of Agriculture and Forestry, in breeding and distributing the various parasites recently brought to Hawaii by Dr. F. Silvestri for the control of the Mediterranean fruit fly. The prospects for the successful establishment of some of these parasites are at present quite promising.

HORTICULTURAL INVESTIGATIONS.

The studies which this station has been making on papaya have been continued during the year, and a bulletin has been prepared[1]. One of the most interesting results of this work is the apparent certainty that within one or two more generations of papaya breeding the diœcious condition in which this tree ordinarily occurs will be eliminated, with great practical advantage to the papaya grower. A strain has already been originated in which over 92 per cent of the trees are self-fertile fruit-bearing trees. This has been accomplished by close fertilization of hermaphroditic flowers, with the result that the occurrence of male trees has already been largely eliminated and the variation due to cross-fertilization thus avoided. It has been found also to be a very easy matter to graft papayas. A union takes place even between the pith of the scion and the stock.

In further work with pineapples it has been found that the shape of the fruit is subject to hereditary transmission as well as other characters. Suckers from plants which bear cylindrical fruits are far more likely to produce cylindrical fruits than are plants which bear conical fruits. Since the cylindrical shape is of considerable importance in canning, for the reason that a larger number of slices of uniform size can be obtained, it is desirable to select suckers with reference to the shape of fruits which they will produce.

There is a constantly increasing demand for hibiscus cuttings for the beautification of army posts and private grounds. The station has done a large amount of hybridizing work with the hibiscus material at hand, and has issued a bulletin on the cultivation of hibiscus, together with a horticultural description of about 235 of the more promising varieties.[2]

CHEMICAL INVESTIGATIONS.

The analytical work necessary in making a general soil survey of Hawaii is practically completed, and a bulletin on this subject is being prepared. Many soils have been found of unusual physical and chemical properties, such as exceedingly high content of titanium, magnesium, humus, lime, and other ingredients, and varying degrees of looseness or compactness of texture. In order to gain an idea of the general processes of change which were taking place in soils in Hawaii, analyses have been made of various samples of lava taken from historical flows of known date. It has thereby been possible to study the formation of Hawaiian soils from the standpoint of their history and to learn the changes which have taken place in the disintegration of lava into agricultural soil. The opportunity for such study is one rarely presented, except in Hawaii.

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[1] Hawaii Sta. Bul. 32.

[2] Hawaii Sta. Bul. 28.

In the study of the nitrogen content of Hawaiian soils it has been found that fallow or virgin soils contain no nitrate, or merely a trace, while the amount of ammonia may be rather large. Upon thorough cultivation, however, nitrification takes place quite rapidly, with the result that the form of soil nitrogen is quite different in cultivated and uncultivated soils.

It has long been known that on many soils heat renders the soil constituents much more active, resulting in larger production. This fact is exceedingly conspicuous on nearly all the soils of Hawaii. An elaborate study was made of the effect of various degrees of heat on different soils.[1] In general it was found that all of the essential plant foods and all their mineral elements are rendered much more available and soluble by the application of heat. Certain physical alterations also result from the application of heat, particularly the flocculation of heavy clays. An elaborate series of experiments was made on the fixation of fertilizers in Hawaiian soils. These experiments will soon be brought to a close. It is already apparent that the soils of Hawaii have the power of fixing large quantities of phosphoric acid, potash, and ammonium sulphate, but only minute quantities of nitrate of soda. The bearing of this work upon the practical use of fertilizers is obvious. During the year experiments have been carried on continuously to determine the nature of nitrogen in Hawaiian soils, and the ratio which exists in different soils between lime and magnesia. Both of these matters will soon be brought to a conclusion.

A study of the product of the native rubber tree (*Euphorbia lorifolia*) showed that the latex of this tree, while containing only a low percentage of true rubber, gives a high yield of resin, which has been tested by a number of manufacturers, with a result that it seems to be identical with chicle. An offer of 70 cents a pound has been made for the product, and it is likely that a new industry will soon be established in gathering this product.

Some experiments have been made in an attempt to develop methods of economically utilizing the large quantities of pineapple juice wasted in the canning process. While pineapple juice may perhaps be most economically used by condensing into a sirup to replace a part of the sugar in canning, it may also be used in the production of a good quality of vinegar. By the quick process a vinegar containing from 3½ to 4½ per cent of acetic acid may be produced in 24 hours, and the percentage of acid will increase by subsequent standing. No difficulty is experienced in securing the acetic fermentation after the proper alcoholic fermentation has been brought about, but the main difficulty is encountered in handling the juice so as to prevent an improper fermentation at the start, thus destroying the flavor of the vinegar or preventing the formation of sufficient alcohol.

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[1] Hawaii Sta. Bul. 30.

AGRONOMICAL INVESTIGATIONS.

During the year the agronomist devoted his attention chiefly to the present status of forage crops in the Territory and methods of producing larger quantities of feed for stock. The fact that large quantities of Australian beef have been shipped to Honolulu indicates the desirability of producing more beef, of better quality, upon the ranches. The areas of corn are rapidly increasing, particularly in connection with ranch work. Much assistance has been given by the station in extending the growing of corn and encouraging the erection of silos for preserving corn, legumes, cane tops, and various other forage crops. During the year several silos were constructed and others are in process of construction. A general survey is being made of the ranches in order to gain information about the growth of various kinds of native and introduced grasses, with the idea of being in position to help in the further improvement of the grazing areas. For this purpose experiments have been carried on with a large number of legumes, grasses, and other forage crops. Some of these have shown striking value under Hawaiian conditions. Data are gradually being accumulated which will help in determining more closely the seasons in which field corn and sweet corn can be grown profitably.

Difficulties have been almost universally experienced in growing potatoes and cotton. Two root diseases attack the potato, and one of them is of an unusually serious nature. In some localities it is impossible to escape the disease oftener than one year in ten. There seems to be little or no difference in the resistance of different varieties to the disease. Experiments are now under way, however, to determine whether a resistant strain can be developed. Before the existence of this disease in Hawaii no difficulties were experienced in growing potatoes. With the cotton the most serious obstacle is the pink bollworm, which continues to breed in undiminishing numbers. This insect lives also in the pods of other members of the mallow family, particularly in the hibiscus. There seems to be no really practicable artificial remedy for the pink bollworm so long as cotton fields are surrounded by uncultivated fields in which stray plants of cotton and other mallows are growing. Some importations of parasites of the pink bollworm have been made from India, without success. It is hoped during the coming year that a more effective parasite may be obtained from Africa. The station has distributed cuttings and tubers of the ordinary mainland sweet potato throughout the Territory. This variety is far superior in flavor to the varieties commonly grown in Hawaii, and in moderately dry and loose soil yields heavily. The crop of tubers, however, is unsatisfactory on heavy clay soils, particularly where the rainfall is heavy.

MISCELLANEOUS.

The experiments conducted by the station on kukui oil have attracted the attention of oil chemists and oil dealers in various parts of the world. Urgent inquiries have been received from 30 or more large oil dealers as to where the oil can be obtained in commercial quantities, and how much can be depended upon as an annual crop. The requests received indicate that 100,000 barrels of kukui oil annually would readily find sale at a price somewhat above linseed oil. Three firms are now preparing for the collection of the nuts and the production of the oil.

The development of the algaroba-meal industry is proceeding at a rapid rate. The rights to pick beans from large areas of Government land and private estates are now sold to the highest bidder for a long term of years. The yield per acre of these beans proves to be much larger than was estimated before reliable statistics on the subject were had. According to the figures as to the harvest for the past year the yield varies from 2 to 10 tons of beans per acre. The product is being used more and more widely, and has been introduced into the ration for Army horses in Hawaii.

For several years there has been a demand for dried roselle beyond what could be furnished from the small patches of this plant heretofore grown in Hawaii. In the experiments of the station it was found that roselle grew very satisfactorily between the young rubber trees and elsewhere. An area of 100 acres was planted this year to roselle for the purpose of obtaining the dried product for use in the manufacture of jams and jellies. One jam manufacturer has found it possible to pay 40 cents a pound for the dried product, and this price yields a reasonable return to the grower.

There are a number of chicken diseases in the Territory, but perhaps the most prevalent is sorehead. This trouble in many instances appears to be associated with the occurrence of eye worm of chickens. Since little was known about the life history of the eye worm a study was made of this problem, during which the greater part of the life history of the eye worm was worked out and the results published in a bulletin dealing with that subject.[1] The method of treatment for eye worm recommended in the bulletin has since been generally used with good results.

As a result of the experiments carried on at the station in dynamiting land, this method of securing drainage has been quite widely tried, with excellent results. It has been found possible to bring about fine drainage in soil on which satisfactory drainage conditions could not otherwise be produced, by exploding sticks of dynamite at depths of 4 feet, at points 20 feet apart both ways throughout the field. If the soil is well tamped it does not disturb the surface appreciably. It has, therefore, been found possible to dynamite pineapple fields immediately after the first crop has been taken off, and in this way start the growth for the ratoon crop more rapidly than was otherwise possible, and also to prevent the packing of the soil beneath the level of cultivation as well as surface erosion.

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[1] Hawaii Sta. Press Bul. 43.

During the year the following publications were issued by the station, totaling 610 pages:

Annual Report for 1912.
Production and Inspection of Milk.
Bulletin 27, Insects Injurious to Corn.
Bulletin 28, Effect of Manganese on Pineapple Plants, and the Ripening of the Pineapple Fruit.
Press Bulletin 37, *Euphorbia lorifolia,* a Possible Source of Rubber and Chicle.
Press Bulletin 38, The Use of Dynamite in Farming.
Press Bulletin 39, The Extraction and Use of Kukui Oil.
Press Bulletin 40, Silos, Silage, and Silage Crops for Hawaii.
Press Bulletin 41, Tin Cans *v.* Pots for Seedling Plants.
Press Bulletin 42, Corn Culture and Improvement.
Press Bulletin 43, Eye Worm of Chickens.
Press Bulletin 44, Plantation Rubber in Hawaii.

REPORT OF THE ENTOMOLOGIST.

By David T. Fullaway.

The entomologist was present at the station and engaged in various lines of investigation continuously throughout the year save for a brief period in December-January, when he accompanied a scientific expedition to the islands lying northwest of Hawaii to investigate and report upon the insect fauna of these outlying portions of the archipelago. The routine work of the office was attended to as usual and the insect collection and library were enlarged by many accessions of material and books. The inspection of plants under the new horticultural inspection board regulations consumed a great deal of time which might have been more profitably employed.

LAYSAN INSECTS.

As a result of the expedition above mentioned, a fine collection of insects from Laysan Island is at hand, throwing considerable light on the fauna of these low islands, which was previously known only from half a dozen or so specimens brought back by earlier visitors. The collection includes about 60 species, at least 5 of which are new to science and will be described by specialists elsewhere,

The following preliminary list will give an idea of the nature of the fauna:

Euplexoptera.

1. *Anisolabis annulipes.*
2. *A. maritima?*

Orthoptera.

3. *Periplaneta americana.*
4. *Polyzosteria soror.*
5. *Phyllodromia* sp.

Corrodentia.

6. *Ectopsocus fullawayi.*
7. *Kilauella* sp. This and preceding species determined by Enderlein.

Thysanoptera.

8. Thrips.

Hemiptera.

9. *Reduviolus blackburni.* Also collected by Schauinsland.
10. *Oronomiris hawaiiensis.*
11. *Nysius* sp.
12. *Triphleps persequens.*
13. *Kelisia* n. sp.
14. *Aphis* sp.
15. *Saissetia nigra.*
16. *Pseudococcus* sp.

Diptera.

17. *Lucilia* sp.?
18. *Musca domestica.*
19. *Hydrophorus* sp.
20. *Lispe* sp.?
21. *Scatella hawaiiensis sexnotata.*
22. Tachinid. Unidentified.
23. Drosophilid. Unidentified.
24. Agromyzid. Unidentified.
25. Phorid.

COLEOPTERA.

26. *Dermestes cadaverinus.*
27. *Attagenus plebinus.* Collected by W. A. Bryan.
28. *Necrobia rufipes.*
29. *Alphitobius diaperinus.*
30. *Macrancylus linearis=Haloscenus immigrans.* Determined by Perkins.
31. *Oodemas* n. sp.
32. *Rhyncogonus* sp. Collected by W. A. Bryan.
33. *Tribolium ferrugineum.*
34. *Calandra oryzæ.* In stores.
35. *Scymnus vividus.*
36. *S. discidens=S. debilis?*
37. *Stephanoderes* sp.?

LEPIDOPTERA.

38. *Euxoa eremioides.*
39. *E. procellaris=Prodenia* sp. of Perkins.
40. *Agrotis dislocata.*
41. *A. saucia.* Collected by G. P. Wilder.
42. *Nesamiptis laysanensis.* Swezey MS. sp.
43. *Pyrausta dryadopa.*
44. *Hymenia recurvalis.*
45. *Omiodes laysanensis.* Swezey MS. sp.
46. *Crocodosema plebiana.*
47. *Hyposmocoma notabilis.* Only the case recovered.
48. *Trichoptilus oxydactalus?* Collected by G. P. Wilder.
49. Tineid. Unidentified.
50. Tineid. Unidentified.

HYMENOPTERA.

51. *Tetramorium guineense.*
52. *Monomorium gracillimum.*
53. *M. minutum.*
54. *Tapinoma melanocephala.*
55. *Phænopria* sp.
56. *Tropidopria* sp.
57. Wingless encyrtid—Ectromini.
58. *Eupelmus* sp. Collected by G. P. Wilder; determined by Perkins.
59. A mymarid.
60. *Chelonus blackburni.*

BEES.

The earlier part of the year was given to an investigation of the bee industry in connection with some special work on bees—an attempt to fertilize queen bees artificially. While the work has so far given no practical results, it has not been entirely abandoned, and from the entomologist's experience of the methods followed in practical bee keeping a manual of bee keeping for use in the islands has been prepared for publication.

GARDEN INSECTS.

The principal investigation of the year has been of insects injurious to vegetables. On its completion this work will be published in bulletin form. For the present a list is furnished of the injurious forms in connection with the main vegetable crops, with reference to previous work on the subject.

Insects injurious to cabbage, turnip, radish, and other cruciferous crops:[1]
- Cabbage butterfly (*Pieris rapæ*) on cabbage.
- Imported cabbage webworm (*Hellula undalis*) on cabbage, daikon, and radish.
- Diamond-back moth (*Plutella maculipennis*) on cabbage, shirona, turnip, watercress.
- Cabbage aphis (*Aphis brassicæ*) on cabbage, daikon.
- Peach aphis (*Myzus persicæ*) on cabbage, shirona, daikon, turnip, watercress.
- Cabbage-leaf miner (*Agromyza diminuta*) on shirona, daikon, turnip.
- Melon fly (*Dacus cucurbitæ*) on cabbage.
- Cutworm (*Agrotis ypsilon*) on turnip.
- Cutworm (*Agrotis crinigera*) on cabbage, turnip.
- Cutworm (*Caradrina exigua*) on cabbage, daikon.
- Common plusia (*Plusia chalcites*) on cabbage, daikon, turnip.
- Beet webworm (*Hymenia fascialis*) on daikon.
- Amorbia (*Amorbia emigratella*) on cabbage, daikon.
- Long-horn grasshopper (*Atractomorpha crenaticops*) on cabbage.
- Thrips (*Thrips tabaci*) on cabbage.

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[1] Chittenden and Marsh. The Imported Cabbage Webworm, U. S. Dept. Agr., Bur. Ent. Bul. 109, pt. 3 (1912).

Of these, the serious pests are the cabbage butterfly, the cabbage webworm, the diamond-back moth, and the aphids. The others are of more or less indifferent nature so far as any actual damage to the crop is concerned. Little can be suggested in the way of remedies, as all the insecticides experimented with by Marsh failed to give appreciable results. In his experience and also in the writer's there is decided advantage in growing under cover until the plants are ready to be set out. The agromyzid fly is very prevalent on all thin-leaved crucifers, but does no great damage. It has some very interesting parasites, which keeps it fairly well checked.

Insects injurious to apiaceous plants—celery, parsley, carrots:
  Cabbage aphis (*Aphis brassicæ*) on celery, carrots.
  Cabbage-leaf miner (*Agromyza diminuta*) on celery, carrots.
  Thrips (*Thrips tabaci*) on celery.
  Common plusia (*Plusia chalcites*) on celery.
  Amorbia (*Amorbia emigratella*) on celery.
  Cotton aphis (*Aphis gossypii*) on celery.
  Mealy bug (*Pseudococcus virgatus*) on carrots.

The only serious pest is the aphis, but it is not very common, and is easily controlled with tobacco sprays.

Insects injurious to potato, tomato, eggplant, and other solanaceous plants:
  Potato tuber moth (*Phthorimæa operculella*) on eggplant, tomato, potato.
  Flea beetle (*Epitrix parvula*) on poha, eggplant, tomato, potato.
  Melon fly (*Dacus cucurbitæ*) on eggplant, tomato, peppers.
  Fruit fly (*Ceratitis capitata*) on peppers.
  Tobacco-pod borer (*Heliothis obsoleta*) on tomato.
  Tobacco hornworm (*Phlegethontius quinquemaculatus*) on tomato.
  Rot fly (*Acritochæta pulvinata*) on peppers.
  Aphis (*Aphis gossypii*) on eggplant, tomato.
  Aphis (*Myzus persicæ*) on peppers.
  Aphis (*Macrosiphum circumflexum*) on poha.
  Cutworm (*Spodoptera exigua*) on tomato, peppers.
  Amorbia (*Amorbia emigratella*) on tomato.
  Plusia (*Plusia chalcites*) on eggplant, tomato.
  Mealy bug (*Pseudococcus nipæ*) on eggplant.
  Mealy bug (*Pseudococcus virgatus*) on eggplant.
  Armored scale (*Saissetia nigra*) on eggplant.

The serious pests are the tuber moth and flea beetle on the stems and leaves and the melon fly on the fruit. For the former, arsenic sprays are recommended. The latter can be kept off by screening or bagging the fruit.

Insects injurious to cucumber, pumpkin, squash, and other cucurbits:[1]
  Melon fly (*Dacus cucurbitæ*) on cucumber.
  Melon stem borer (*Apomecyna pertigera*) on cucumber.
  Beet webworm (*Hymenia fascialis*) on cucumber.
  Cutworm (?) on squash.
  Rot fly (*Acritochæta pulvinata*) on squash.
  Plusia (*Plusia chalcites*) on squash.

The serious pests here are the melon fly and the stem borer and very little can be done in a practical way to prevent their great destructiveness.

Insects injurious to spinach and other amarantaceous plants:[1]
  Beet webworm (*Hymenia fascialis*) on spinach, beets.
  Wireworm (?) on beets.
  Cutworm (*Spodoptera exigua*) on beets.
Insects injurious to onions and other alliaceous plants:
  Thrips (*Thrips tabaci*) on onions, leeks.

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[1] Marsh. The Hawaiian Beet Webworm, U. S. Dept. Agr., Bur. Ent. Bul. 109, pt. 1 (1911).

Insects injurious to miscellaneous vegetables:
- Cutworm (*Spodoptera mauritia*) on asparagus.
- Cutworm (*S. exigua*) on okra, cauliflower.
- Cotton aphis (*Aphis gossypii*) on taro and other aroids, okra.
- Japanese beetle (*Adoretus tenuimaculatus*) on taro and other aroids, string beans.
- Peach aphis (*Myzus persicæ*) on rhubarb.
- Amorbia (*Amorbia emigratella*) on okra.
- Root maggot (*Phorbia fusciceps*) on garden beans.
- Long-horn grasshopper (*Xiphidium varipenne*) on garden beans.

MEDITERRANEAN FRUIT FLY.

The Mediterranean fruit fly has been quite as destructive to practically all soft-pulped fruits this year as last, in spite of a concerted effort to control it by the practice of clean cultivation. Pineapples, grapes, and berries are notable exceptions to the long list of fruits which the fly attacks. Most other fruits are generally infested and the only practical means of protection so far discovered is bagging individual fruits or entire trees.

A beginning has been made in the introduction of natural enemies. On May 16, Dr. F. Silvestri, of the Royal School of Agriculture at Portici, Italy, who had been engaged in the summer of 1912 to search for parasites in West Africa, arrived in Honolulu with numerous examples of seven species of fruit-fly parasites obtained in Africa and Australia. Following out an agreement made several years previous the station has continued to advise the Territorial authorities in regard to this work, and the entomologist has followed with much attention the details of Dr. Silvestri's investigations. Since his arrival the entomologist has given his whole time to the multiplication and distribution of the parasites, and at the present writing there seems to be good ground for believing that at least some of the parasites will become established here and prove effective checks on the fruit fly. An extended report of this work will be made later. At present it can be stated that the two parasites of the pupa of *Ceratitis capitata,* which were brought in large numbers by Dr. Silvestri—one a chalcidid and the other a diapridid—breed readily in the laboratory and can be distributed by the thousands. The larval parasites (species of Opius) were brought in small numbers and are much more difficult to propagate. One or two species as well as other species of pupal parasites show a decided tendency to run to males and thus prevent further multiplication. The work of propagation is being very carefully attended to and will be continued until it is certain that the species have become established or the material fails. As previously stated, with some of the species there is every chance of ultimate success in their establishment under natural conditions.

REPORT OF THE HORTICULTURIST.

By J. Edgar Higgins.

No new projects of importance were started during the year in the work of the horticultural department. Some of the investigations with papayas and with pineapples have reached fruition, and results are apparent in the case of some peach tree pruning experiments. It is also possible to report upon a few minor subjects that have been under experiment.

THE PAPAYA.

Considerable attention has been given to the papaya investigations, which have been under way for several years, and in which results are beginning to be achieved. In an experiment in breeding with hermaphrodite flowers fertilized with their own pollen, it was found that in the first generation of 343 trees, 322 were fruit bearing, or about 93½ per cent. A careful study has been made of all the available literature relating to the papaya, both from the purely scientific point of view and from that of applied knowledge. Through the courtesy of the library of the United States Department of Agriculture, it has been possible to secure the use of several valuable publications which would not otherwise have been available. The library of the Bishop Museum and those of the Hawaiian Sugar Planters' Experiment Station and the College of Hawaii have afforded valuable assistance. This literature has to some degree led into the perplexing problems of sex inheritance. Correspondence with botanists and horticulturists in many parts of the Tropics have brought out valuable data relating to the status of the papaya and other species of Carica in such countries. To all of the scientists and institutions referred to it is desired to express thanks and appreciation. Through the botanic gardens and experiment stations it has been possible to secure seeds of papaya and some other species of Carica from many countries. However, many species from their native habitat in Central America, South America, and Mexico are desired.

The results of the papaya investigations up to June, 1913, have been brought together as a bulletin of this station.[1]

Since the presentation of this bulletin two rather important features have developed which may be mentioned here. One of these is a papaya disease which has just appeared and which is quite new to the station. It appears to be characterized by a wilting of the leaves and a decay of the stem, causing the sudden and entire destruction of the tree. The disease is being studied by Dr. H. L. Lyon and Mr. L. D. Larsen, pathologists of the Hawaiian Sugar Planters' Experiment Station, and every precaution is being taken to prevent its spread.

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[1] Hawaii Sta. Bul. 32.

The change in sex of a papaya tree from male to female brought about at times apparently by the cutting back of the top of the tree has been discussed in the bulletin above mentioned, where it was shown that this change takes place only occasionally. Many young male trees of a lot in which the females had matured no fruit were subjected to the removal of the growing portion at the end of the stem. These have not been reported upon. In several instances there appears to be a large increase in the number of hermaphrodite flowers in the inflorescence just below the wound, although many of the trees showed no change whatsoever. None became pistillate trees, and it can not be observed that the new branches bear any more hermaphrodite flowers than the original stem.

A similar experiment was conducted with 15 male trees out of a lot of 16 which were several years old. Seven of these were cut off about 18 inches above the soil, and eight were cut leaving a stem about 4½ feet high. The hollow space within was filled with volcanic ash, covered with plaster of Paris. Four of those cut low and one cut high have sent out no shoots. It is believed from this experience that old trees should not be cut lower than 4 or 5 feet in such tests. None have yet shown any pistillate or hermaphrodite flowers. Some of the branches are without flowers of any kind and may later show new characters.

THE PINEAPPLE.

Two interesting lots of pineapple seedlings are under observation and study. Lot No. 3059 were grown from 131 seeds taken from a single fruit and donated by the Thomas Pineapple Co. (Ltd.). They were collected September 10, 1912, and were the only seeds found in the fruits that passed through the company's cannery during the season's pack, a fact illustrating the rarity of seeds in the varieties grown here. It is not known whether the fruit was the ordinary Smooth Cayenne or of the Queensland variety.[1] The seeds were planted promptly and in two months 72 had germinated in the warm box of the glass house referred to in the report of the assistant horticulturist (p. 27). These seedlings are showing very wide variation. In vigor they range from the very weak to very robust; in color of foliage from dark green to bronze; in habit from upright to procumbent; and from the very spiny to those which it is necessary to examine carefully in order to find any spines.

At about the same time a similar lot of 148 seeds was received from Ginaca Bros., Maunawai, Oahu, which also were taken from a single fruit. These were planted as No. 3060, under the same conditions, 74 of the seeds germinating. They exhibited fully as wide variations as the other lot, as may be seen by reference to the illustration (Pl. I, figs. 1 and 2).

SELECTION OF PLANTS BY FORM OF FRUITS.

It is a matter of great importance to pineapple canners to have fruits of as nearly uniform diameter as possible. Those that are tapering often entail too much waste by reason of the upper slices being too small for first grade in packing. For this reason it seemed desirable to conduct some experiments to determine whether these differences among plants supposedly of the same variety are purely incidental to environmental conditions, or whether they represent characters which may be transmitted through propagation by asexual parts, as suckers, crowns, or slips.

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[1] See Hawaii Sta. Press Bul. 36, pp. 21, 22.

In September, 1910, some plants were selected for preliminary experiment. Those which appeared to the eye to be inclined to the tapering form were selected as such, were measured and divided as follows: Lot 100 (crowns), lot 200 (slips), and lot 300 (suckers). Measurements were taken by placing a carpenter's square over the top of the fruit after the removal of the crown, and taking caliper measurements every inch, beginning 1 inch from the crown. Those fruits appearing to the eye to be barrel shaped or of fairly uniform diameter, were classed as lot 400 (crowns), lot 425 (slips), and lot 450 (suckers). These were all planted at the Thomas Pineapple Co.'s lands at Wahiawa on October 4, 1910. On July 26, 1912, the fruits of the progeny were gathered, except those that had already matured and had been sent to the cannery by mistake by the laborers. The fruits of suckers of lot 450 had all been gathered, and only two fruits remained of lot 300, which also was left out of the calculations on this account. A summary of the measurements is given in the accompanying table.

Tabular summary of measurements of pineapples.

Lot.	Selected as—	Crowns, slips, or suckers.	Difference in diameter, top and bottom slices, 1910.			Difference in diameter, top and bottom slices, 1912.			Average totals.
			Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	
			Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
100	Tapering......	Crowns.........	2.125	1	1.534	1.687	0.812	1.102	1.186
200	.....do.........	Slips...........				2.5	.812	1.212	
300	.....do.........	Suckers........							
400	Square.........	Crowns........	1.375	.562	.806	1.375	.812	1.02	.932
425	.....do.........	Slips...........				1.187	.437	.787	
450	.....do.........	Suckers........							

From a study of the above table it would appear that plants bearing pineapples having an average difference in the diameter of their top and bottom slices of 1.534 inches have produced fruits with an average difference of 1.186 inches in diameter. Plants from fruits whose average difference was 0.806 inch have produced fruits with an average difference of 0.932 inch. Such evidence as this experiment affords from a study of the measured fruits points toward a probable transmission of form characters by asexual propagation.

In this connection not only the averages should be studied, but the maximum and minimum variation. It will be seen that the maximum differences in diameter in fruit of parent plants is very close to the maximum in the progeny, both in the "square" and in the "tapering" fruit. The same is true of the minimum diameter variation of parent compared with progeny.

Another means of testing this matter is now being employed. Individual plants of marked character are being selected as they are found. The fruit of each of these is measured separately, and the progeny is being related to the exact plant from which it was taken. None of these has yet come to maturity.

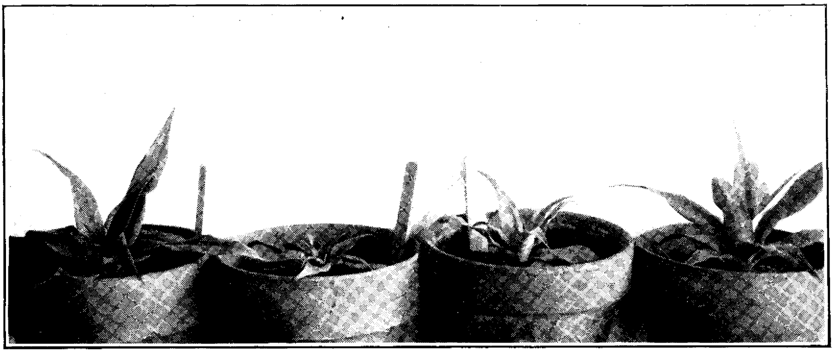

FIG. 1.—PINEAPPLE SEEDLINGS OF NO. 3060.

[Note the wide variation in habit of growth.]

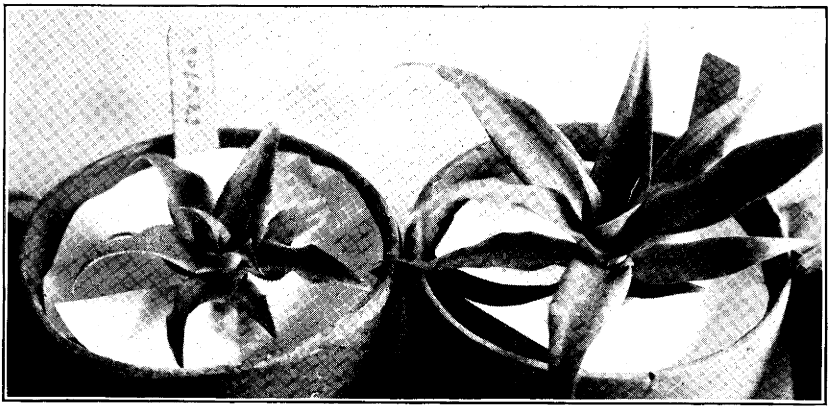

FIG. 2.—PINEAPPLE SEEDLINGS OF NO. 3060, SHOWING SMOOTH AND SPINY PLANTS.

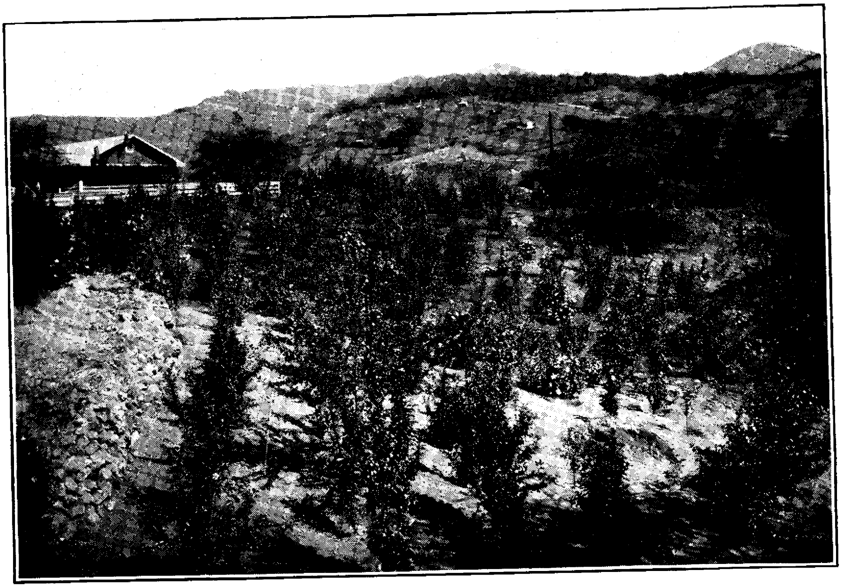

FIG. 1.—GENERAL VIEW OF HIBISCUS GARDEN.

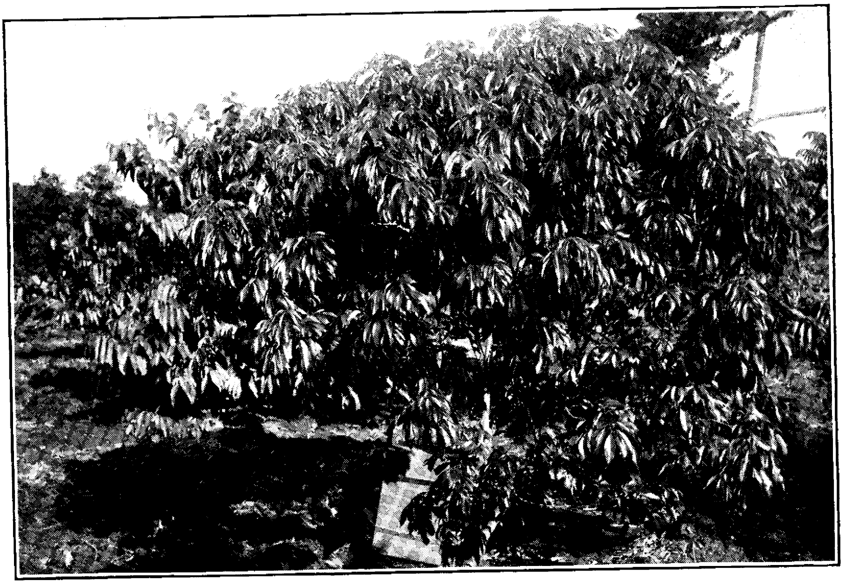

FIG. 2.—LITCHI TREE, FIVE YEARS AFTER PLANTING.

PEACH-TREE PRUNING.

Several years ago some simple experiments were undertaken to determine the best seasons and methods for the pruning of the peach in the tropical climate of the lowlands of this Territory. These have been continued. Without going into the details of the work, it may be stated that the best results have been secured by a severe pruning which is almost the equivalent of a renewal system. This pruning is done in June, very soon after the gathering of the fruit. The tree is almost without foiliage after the pruning, but soon sends out many new branches. It is necessary to go over the trees a little later to remove all suckers that are not required to improve the shape of the tree. The new branches continue to grow vigorously through the summer and fall, suspending their more active growth in the winter and maturing fruit buds.

TOP-WORKING AVOCADOS.

Many of the avocados in the seedling orchard have fruited and such as are not considered worthy of further testing are being top-budded to more valuable varieties. A marked change in method is being tried in this work. Trees 6 or 7 years old have been cut back to stumps about 1½ or 2 feet high, with a sloping cut which has been well covered with heavy paint or wax as a protecting covering. All trees so treated have sent out vigorous shoots which have proved ideal stocks for the reception of buds, being far better in this respect than the side branches of any of the original trees.

CONDITION OF ORCHARDS.

The general condition of the experiment orchards at the present time is excellent. The avocado orchard suffered from insufficient moisture during the prolonged drought of 1912, which probably accounts for a comparatively light crop this year, but the trees have recovered and if sufficient water is available a good crop may be expected in 1914.

The heaviest crop of mangoes that has ever been produced here is now upon the trees, notwithstanding the fact that very many of the fruits were removed on account of the prevalence of the Mediterranean fruit fly. Those remaining are protected with paper coverings. These have not previously been used at the station, and it remains to be seen whether they are to be recommended.

Many of the citrus varieties are fruiting, and budwood from promising kinds has been used in budding nursery stock for distribution.

The orchard of miscellaneous tropical fruits is increasing in interest. The litchi plants imported from China direct, and those received through the Office of Seed and Plant Introduction, are making a very satisfactory growth, and may be regarded as past the critical stage. A tree planted March 14, 1908, is shown in Plate II, figure 2.

The *Feijoa sellowiana* received in March, 1908, from the Southern California Acclimatization Association is fruiting for the first time in Hawaii, having made a satisfactory growth. This is one of the newly introduced fruits, related to the guava, which it resembles in many respects, but is much more delicious, has smaller seeds, and is highly perfumed. The tree with its silvery-gray foliage is attractive in the landscape, and the flowers, which are a mixture of purple, red, and white, are very beautiful.

HIBISCUS.

Mr. Valentine S. Holt, assistant in horticulture, has devoted much time and painstaking energy during the past few years to work with hibiscus, chiefly along the lines of breeding. The details of this work, which has been done with the close personal cooperation of Dr. Wilcox, have been published as a bulletin of this station.[1] Mr. Holt presents some general features of the work, not touched upon in the special publication, as follows:

There are probably few, if any, plants of more promise for ornamentation than the hibiscus. This plant grows in dry and poor soil, and has been planted in various places at the station where nothing else would prosper. While there may be some people who will think that the hibiscus is of little economic importance, it may be said that its popularity is evidenced by the large demand for new varieties. The first Hawaiian exhibition of hibiscus was held during the month of June, 1911, and this astonished even those most familiar with these plants by the number and beauty of the varieties which were brought together. The second exhibition of hibiscus was held in September, 1912, and this surprised the public even more by the very large number of varieties exhibited, which exceeded the first by several hundred flowers. The hibiscus is now receiving much more public attention, and a great many requests have been received for cuttings of this plant.

Over 125,000 cuttings of the different varieties have been distributed. A method has been adopted in this propagation work by which the plants can be multiplied rapidly. Cutting beds have been prepared in the open by using ordinary beach sand. The cuttings are first tied up in bundles of from 100 to 200 and planted in the sand, where they root in three or four weeks. In this way they are easily handled in planting and transplanting.

Some time has been devoted to the breeding of new varieties of hibiscus. The station has now over 3,000 new seedling varieties under observation, which are the results of last year's cross pollinations. Some of these plants are of great beauty in foliage as well as in flower, which will add much to the floral wealth, not only in Hawaii, but in other parts of the tropics and subtropics. A general view of one of the hibiscus gardens is shown in Plate II, figure 1.

ADVICE AND DEMONSTRATIONS.

The usual calls for information and advice increase from year to year. These have been responded to by correspondence and by verbal advice to inquirers at the laboratory, propagating houses, orchards, and nurseries. In many cases which seemed to justify it, visits have been made by members of the staff.

In closing, it is desired to express appreciation of the faithful and efficient services of Mr. Chester J. Hunn, assistant horticulturist, Mr. Valentine S. Holt, assistant in horticulture, and of those who have done the detail work of the propagating houses and orchards.

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[1] Hawaii Sta. Bul. 29.

REPORT OF THE ASSISTANT HORTICULTURIST.

By CHESTER J. HUNN.

BUILDINGS.

As noted in the annual report for 1912, a number of new buildings, more adaptable to prevailing conditions, were in the process of erection. The acquisition of these quarters has necessitated the rearrangement of the whole system of propagation and horticultural supplies. In addition to these new buildings there has been erected a number of outdoor ant-proof tables and several fences for wind protection.

The ant-proof, glass propagation building has been one of the important additions of the past year. The depredations from pests have been reduced to a minimum, while the average percentage of germination with seeds has been greatly increased. The facilities for the regulation of heat and moisture, which are of utmost importance in subtropical propagation, have been greatly augmented by the construction of hinged glass frames over the seed and cutting propagating beds. While the bottom heat derived from the solar heater has been very satisfactory during the afternoons of sunny days, there is still much to be desired, especially during the mornings and on cloudy days when the heat is not sufficient. Plans by which a gas heater is to be installed are being consummated. This should make the propagation work more effective.

FIELD WORK.

Since the scope of the horticultural work is increasing year by year, the amount of field and greenhouse work is becoming correspondingly greater. The various tree plantings have required staking, pruning, fertilization, fumigating, and spraying. Since the advent of the fruit fly (*Ceratitis capitata*) all fruit, on approaching maturity, has been covered with cloth or heavy paper bags. From time to time new plants have been placed in the fields. It has been found necessary to use heavier copper wire on the tree labels. The plant records have been kept up to date, as usual. The fields in general are in a better condition than several years ago, due to the plowing under of cover crops which are sown yearly just preceding the rainy season.

PEACHES.

The varieties of peaches as grown in California will not succeed at the lower altitudes in Hawaii. There are, however, a number of seedlings of very good quality growing on the various islands. It is the desire of the station to collect budwood of the best seedlings and to bud the same into trees in the station orchard. A number of persons have imported budded stock of the Peento and of the Honey peach groups. This station has under test at the Kauai substation the better known commercial varieties of these two groups. During the past year this station received budwood of both a Bolivian freestone and a clingstone peach. The establishment of a peach industry on the islands rests upon the selection of seedlings, the importation of tropical and subtropical varieties, and upon the control of the Mediterranean fruit fly.

ACCESSIONS.

The varietal collections of avocados, mangoes, and citrus have been augmented by the collection of the better varieties both of Hawaii and of foreign sources. This budwood has been used in the several orchards, from which budwood can later be obtained for distribution. Letters sent to all parts of the tropical and subtropical world in regard to the papaya have resulted in the receipt of many new strains of the papaya, which are now being grown in the test orchard. Among the notable importations should be mentioned numerous packets of seed from Java and Ceylon and a collection of plants from the botanical gardens at Sydney, Australia, both of which were donated to the station by Dr. William T. Brigham, of the Bishop Museum. These include several new varieties of *Nephelium lappaceum*, *N. mutabile*, and *Lansium domesticum*.

DISTRIBUTIONS.

While this department makes no pretense of keeping a supply of plants for distribution, cuttings of the surplus hibiscus and other ornamentals, as well as seedling fruit trees, have been distributed during the past year. One of the ways in which this station can assist the general public in building up a home or a commercial fruit industry is to distribute the better varieties of avocados, mangoes, and citrus. Such plants, either budded or grafted, have been sold at a nominal figure to cover the expenses of propagation and to make the trees something to be desired. The citrus trees have been sold as "balled" budded nursery stock, while the avocados and mangoes have been distributed growing in the gallon tin containers in which they were budded or inarched. This department has from time to time filled requests made by other scientific institutions.

PROPAGATION BULLETIN.

Considerable time has been devoted during the past year to the collection of data, from actual experimental work and otherwise, for a bulletin on propagation. This publication will be amplified by the addition of lists of plants suitable for planting in Hawaii.

REPORT OF THE CHEMIST.

By W. P. Kelley.

The work of the chemical department during the year has been devoted very largely to soil investigations. In addition to the analysis of a large number of samples collected in connection with the general soil survey that has been under way for several years, a considerable number of soils have been examined for special purposes, particularly with reference to the occurrence of manganese. The pineapple growers have become so generally aware of the detrimental effects of excessive manganese that ever-increasing demands are made on the station for information regarding the amounts of manganese in the new lands that are being opened up for pineapples. Study of certain special soil problems has also occupied considerable attention; a study of nitrification and ammonification, the effects of heat on soils, the fixation of fertilizers, a study of the organic nitrogen of typical island soils, etc., being the chief problems investigated. Some time has also been given to a study of certain agricultural products, such as the rubber-containing latex from *Euphorbia lorifolia,* the kukui-nut oil, and waste pineapple juice.

SOIL SURVEY.

The meager state of knowledge concerning the extensive upland areas, and the increasing importance attached to these sections by virtue of the increased demand for new lands, have emphasized the need of securing as much information regarding these soils as possible. The general soil survey that has been under way for some time has therefore occupied a larger share of the attention of this department than during any previous year. Several hundred samples have been collected, so as to represent as completely as possible the various uplands, and these have been subjected to chemical and physical analyses. The work bearing directly on this survey is practically completed and a report on it is being prepared for publication.

The making of a soil survey in Hawaii, in the sense it is understood in the States, is extremely difficult, for the reason that soil types can not be so definitely located. Great variations occur within short distances without necessarily bearing any definite relationship to the topography. Neither can the types be traced with any degree of certainty from superficial examination. Often local spots, small in area, but peculiar in composition, are found surrounded by a number of other types. The soils of Oahu, however, have been very thoroughly sampled—so thoroughly that it is safe to conclude that all the important types have been located. On the other islands it has not been feasible to go into as much detail. A number of samples have been taken from every district, however, so that it is possible to discuss the island soils generally, with small probability of going far astray.

A number of unusual soil types have been located and considerable data have been accumulated with reference to these. It has been the purpose in this investigation, in addition to accumulating data with reference to the empirical composition of the soils from the different sections, to learn as much as possible regarding their properties, modes of formation, the trend of changes which they are undergoing, and the best methods of management.

LAVA ANALYSIS.

A number of samples of lava, representing the various lava flows of easy access, were analyzed, with the idea that the composition of the lava from which all the island soils have originated, with that of the soils themselves, would throw light on the nature and course of changes now occurring in the soils. The results of absolute analyses of the lava samples are given in the following table:

Analysis of Hawaiian lavas.

Constitutents.	From Oahu.				From Hawaii.					
	A.	B.	E.	F.	501	502	503	504	505	519
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Silica (SiO_2)	52.45	52.15	51.98	52.24	48.88	48.55	52.07	51.25	49.94	50.69
Alumina (Al_2O_3)	11.49	12.57	15.85	16.00	12.84	14.83	14.12	14.36	14.42	15.62
Ferric oxid (F_2O_3)	3.66	3.36	2.90	3.73	.30	2.44	2.64	3.30	1.04	.49
Ferrous oxid (FeO)	6.90	7.07	6.84	5.89	8.52	6.07	7.01	6.43	8.01	4.65
Manganese oxid (Mn_3O_4)	.36	.50	.92	.68	.31	.66	.72	.44	.20	.28
Lime (CaO)	10.32	8.54	9.57	9.54	9.55	8.56	10.71	10.65	11.59	11.14
Magnesia (MgO)	5.81	6.51	5.61	5.90	10.29	14.22	7.51	9.12	9.08	6.55
Potash (K_2O)	.89	.84	.97	.86	.75	.72	.74	.64	.80	.90
Soda (Na_2O)	2.44	2.64	2.70	2.65	1.44	1.56	1.93	1.96	1.79	2.56
Sulphur trioxid (SO_3)	.20	.61	.51	.53	.33	.19	.35	.33	.33	.78
Phosphorus pentoxid (P_2O_5)	.38	.28	.22	.11	.21	.22	.24	.17	.26	.34
Titanic oxid (TiO_2)	4.07	4.07	1.50	1.50	2.54	2.15	2.42	2.35	2.86	5.53
Combined water (H_2O)	1.02	.94	1.04	.54	4.45	.09	.00	.00	.00	.10
Total	99.99	100.08	100.61	100.17	100.41	100.26	100.46	101.00	100.32	99.63

A striking feature of these analyses is the close similarity in the composition of the several lava flows from the island of Hawaii. It is also noteworthy that the lavas from Hawaii on the whole are very similar in composition to the normal basalts of Oahu. The four samples from Oahu were taken from excavations recently made in the Wahiawa district, and, so far as could be judged, had undergone very little alteration since they had been laid down. The samples from the island of Hawaii, with the exception of Nos. 505 and 519, represent flows of definite dates coming from the volcano Mauna Loa, and all the samples were taken from exposed places.

Sample No. 501 came from the flow of 1823, and had begun to undergo slight alteration, as shown by the combined water and a slightly reddish tinge, in contrast to the normal dark gray color. A slight leaching had also taken place. Sample No. 502 represents the flow of 1868 and was taken at an elevation of 1,800 feet. This lava also showed slight changes in appearance, which were evidently due to hydration, slight leaching, etc. No. 503 came from the flow of 1883, No. 504 the flow of 1907, and No. 505 represents the small flow that occurred near Christmas, 1910, when the volcano Kilauea arose to near the surface, small amounts of lava having been deposited on the ledges, from which the analytical sample was secured. The chemical composition of these different flows presents a striking similarity in the percentages of the several constituents, with the exception of the magnesia, which was found to be quite irregular, and in each instance present in larger quantities than occurred in the basalts of Oahu. The sodium content, on the other hand, occurs in smaller quantities than was found in the samples from Oahu. In other respects the lavas from the two islands are very similar in composition.

No. 519 represents a sample of the material known as "Pele's hair," which is made up of fine hairlike threads of lava, formed when bubbles of escaping gases are suddenly forced out of the molten lava of Kilauea, the explosive force being so great that small portions of the molten lava are spun out into threads, which are caught by the wind and blown some distance away. The composition of this material shows it to be quite similar to the normal lava of Oahu.

NITRIFICATION AND AMMONIFICATION.

The great importance now attached to the biological processes going on in the soils, particularly such processes as have to do with the rendering available of soil nitrogen, suggested the desirability of investigations on nitrification and ammonification. It is now well known that, while these processes are due to organisms, various chemical and physical factors exert great influence on the intensity of the changes brought about by them. The soils of Hawaii, as previously pointed out, are extremely abnormal in many respects; generally they contain unusually high percentages of iron oxid and alumina, and not infrequently abnormal quantities of magnesia. The physical make-up of these soils is also peculiar. The clay, which is present in very high percentages, is composed of substances differing in composition from normal clay. Climatic factors are also extremely variable, and sometimes very abnormal.

From preliminary studies it was found that the average soil contains a very low percentage of nitrate and rather large amounts of ammonia. In this work considerable attention has been given to partial sterilization as affecting these processes, and some interesting results have been obtained. The full details of this investigation have been brought together in a separate publication.[1]

EFFECTS OF HEAT ON SOILS.

The remarkable effects on ammonification observed to follow partial sterilization by means of heat suggested a study of the effect of various temperatures on the solubility of the soil constituents. Remarkable changes were observed to take place as a result of heating, practically all the soil constituents being greatly increased in solubility. This phase of the investigation has already been reported upon in a separate bulletin[2] and therefore need not be discussed here, further than to mention that the effects of heat on soils are extremely complicated. In addition the data show that burning very greatly affects the solubility of soils.

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[1] Hawaii Sta. Bul. 31.

[2] Hawaii Sta. Bul. 30.

FIXATION OF FERTILIZERS.

The comparatively large amounts of fertilizers used in the islands, sometimes in districts of extremely heavy rainfall, suggested the desirability of securing definite data with reference to the leaching of fertilizers from the soils. The subject of fixation of fertilizers has been studied extensively in most parts of the world, but only to a limited extent on soils similar to those of Hawaii. This work is being carried out by Mr. McGeorge, assistant chemist, and is now well under way. The data already secured show that the fixing power of Hawaiian soils is remarkably high, especially for phosphoric acid. The maximum fixing power for phosphoric acid of the soils studied has not yet been determined. In some instances as much as 0.8 gram of P_2O_5 has been fixed by 100 grams of the soil without its showing any diminution in fixing power. The fixation of potash and of nitrogen in the form of ammonia has also been found to be high, but seems to reach a maximum within a comparatively short time. A point of special interest in this connection has to do with the fixation of nitrate. For many years, enormous quantities of nitrate of soda have been applied throughout the islands, sometimes in districts where the precipitation may average as much as 300 inches per annum. The data already obtained show conclusively that nitrate of soda is not retained by these soils, the leachings showing that in a very short time the nitrate passed through the soil. This naturally raises the question concerning the real explanation of the fact that nitrate of soda frequently produces enormous increase in the yields of cane, although applied in a single application at an early period in the growth of the crop. This work is being continued with a view of obtaining data on the effect of heat on the fixing power, the effects of sterilization, etc.

SOIL ORGANIC NITROGEN.

In 1911 some preliminary studies were reported from this station on the organic matter of Hawaiian soils.[1] This subject has again been taken up, mainly, however, with reference to the nitrogenous constituents. When it is recalled that practically all the nitrogen of soils exists in organic combinations, and that these are subject to various changes, induced by biological agents which seem necessary before the nitrogen becomes available for plant growth, it is at once apparent that any additional information that can be obtained regarding the changes in the chemical combinations taking place in soil nitrogen can but lead to a better understanding of the biological processes going on and may prove of great practical value. The wide range of climatic conditions in Hawaii, particularly with reference to the rainfall, affords ample opportunity for a study of extreme variations as brought about by moisture content of Hawaiian soils. Considerable areas of the islands are maintained in a practically continuously submerged condition, whereas arid areas are not uncommon. It was suggested, therefore, that a study of the hydrolytic products obtainable from soils coming from these two widely differing sets of conditions might give some indication as to the fundamental nature of the anaerobic and aerobic hydrolyses.

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[1] Hawaii Sta. Press Bul. 33.

The question of the composition of so-called humus, with particular reference to its nitrogen and the humification process, have been subjects of much speculation, and apart from a few special investigations little indeed is really known about them. It is true most agriculturists consider that organic matter must undergo a process termed humification before it becomes of the greatest value to soils, but just what is implied by humification is far from being definite and is little understood. A study of humus with reference to its nitrogen, to gain some insight into the nature of the cleavages that take place during the humification process, etc., has been begun, and the results will be presented in a separate publication in the near future.

LIME-MAGNESIA RATIO.

The lime-magnesia ratio in soils is now occupying a prominent place in soil investigation throughout the world, and the results obtained to date have given rise to conflicting conclusions. Many of the island soils contain abnormally high percentages of magnesia; in fact the average soil of the islands contains considerably more magnesia than lime, while in some instances the magnesia content is several times that of lime. The soil previously used for rice experiments at the station is one of these abnormal types, analysis of which shows it to contain 1.99 per cent lime and 9.42 per cent magnesia, each of which probably exists, however, largely as hydrated silicates since the carbon dioxid content is low. Some experiments have been carried out in pots, employing varying amounts of both the carbonates and the sulphates of calcium and magnesium, and observing the effects produced on the growth of rice. It will be recalled that some years ago Loew and his coworkers in Japan studied this question extensively with reference to rice and drew the conclusion that a more or less definite ratio of 1:1 was best suited to the growth of rice. Two sets of experiments on this subject have been carried through, the results of which are in conflict. The first series showed that the larger application of magnesium sulphate caused a decrease in the yield, whereas that of calcium brought about an increased growth. In the second set of experiments no such effects were observed, although much larger amounts of these constituents were employed. These results are somewhat puzzling, and no explanation is offered at this time.

It is noteworthy that the use of carbonate of magnesium caused a considerable delay in the maturity of the rice, in harmony with the findings of Voelcker,[1] at the Woburn station. Further comment on this question is reserved for a subsequent publication dealing with the effects of lime and magnesia on ammonification, nitrification, etc.

RUBBER INVESTIGATIONS.

The discovery of the occurrence of large amounts of latex in the tree *Euphorbia lorifolia* called for some study. The latex was found to contain a low content of rubber, but high percentages of two resins. This work has already been published in a press bulletin from this station.[2]

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[1] Jour. Roy. Agr. Soc. England, 73 (1912), pp. 325–338.
[2] Hawaii Sta. Press Bul. 37.

KUKUI-NUT OIL.

The enormous quantities of kukui nuts (*Aleurites triloba* or *A. moluccana*) going to waste throughout the islands suggested the desirability of some study of the oil content in the nuts. Formerly this oil was expressed by the natives and found considerable favor. The nuts were found to contain practically 60 per cent of a quick-drying oil, and the several constants have been determined, as well as its general properties. This work has likewise already been published in a press bulletin.[1]

PINEAPPLE VINEGAR.

In the canning of pineapples, now so extensively carried out in the islands, there is enormous waste of essentially pure pineapple juice, amounting to hundreds of thousands of gallons per annum. For some time past some of the canneries have utilized the waste juice in the making of sirups, and, to a limited extent, for the production of bottled pineapple juice. Notwithstanding these uses, a large amount of this juice is still going to waste. An appeal was made to the station for some assistance in connection with the possible utilization of the juice for the making of vinegar.

The Hawaii Preserving Co. had already erected a series of tanks similar to those used elsewhere in the quick vinegar process, and a series of experiments was carried out in cooperation with this company, using their plant. The results were not entirely satisfactory. On an average the vinegar obtained contained an acetic acid content of about 3.8 per cent, which is considerably below the legal standard. Occasionally it was possible to obtain vinegar of approximately 4½ per cent. The difficulty in this connection appears to be that anything like complete alcoholic fermentation of the sugars in the ordinary juice is extremely difficult to obtain, due to the fact that various other types of fermentation take place simultaneously with it. It is necessary first of all to sterilize the juice soon after it is expressed, and as yet no thoroughly satisfactory method of alcoholic fermentation of the juice has been worked out on a commercial scale. There is no doubt that a vinegar of excellent quality can be obtained provided satisfactory alcoholic fermentation be first secured, but since acetic acid fermentation is dependent first of all upon the alcohol present, a satisfactory vinegar, of course, can not be obtained until the desired concentration of alcohol is first secured. The small price of the product when once it was obtained did not encourage further investigation of the question, but it is hoped that a more extensive study of the question will be undertaken at some future time.

Much of the success of the work of this department is due to the efficient assistance rendered by Mr. McGeorge and Miss Thompson, assistant chemists, and a large share of the credit belongs to them.

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[1] Hawaii Sta. Press Bul. 39.

REPORT OF THE AGRONOMIST.

By C. K. McClelland.

The work in the department of agronomy has been carried on under several handicaps during the past year. One of these was the loss of the rice plats and the necessity of preparing new lands for rice experiments. The lands obtained for this purpose in Nuuanu Valley were abandoned taro patches, grown over with Bermuda grass, coco grass, honohono, and weeds. Three plowings at extended intervals were necessary in order to put this land in shape for cultivated crops. By the time this was done it was too late to put in a fall crop of rice, and corn, soy beans, oats, barley, and peas were planted. In March of the present year rice was planted over part of the area where the soil appeared to be uniform. To test the soil of the new location a fertilizer test was started upon one plat, while upon two adjacent plats a simple test of deep versus shallow submergence was inaugurated. Further experimentation with rice will be made along the lines of rotation of crops and methods of soil management, and no further attention will likely be given to variety trials.

RICE.

As has been mentioned in previous reports, the station has been attempting for some time to produce a rice of a quality equal to that of the imported Japanese rice, and which would be acceptable to the Japanese population. Four varieties were recently introduced for this purpose. After being grown for several generations they have been found wanting, and the attempt to produce rice of this quality will have to be abandoned. The Miyako variety was tested after being grown for three generations, and was found to be greatly deteriorated. The Omachi and Shinriki varieties, after having been grown for five generations, were submitted, with samples of imported rice, to three representative Japanese and also to three Americans who, from residence or sojourn in Japan, were qualified to act as judges of Japanese rice. One of the Americans admitted his inability to distinguish between the three samples, but found them all superior to ordinary Hawaiian-grown rice. The other five selected one of the samples, which proved to be the sample of the imported rice, as being greatly superior to the other two samples. This test proves beyond any doubt that there is a great difference in quality between Japanese-grown and Hawaiian-grown rice, and also proves to our satisfaction that it is vain to attempt to produce a rice equal in quality to the Japan-grown article. While it has been shown that there is no difference in chemical composition, the judges who made this test for the station have pointed out that the differences are in physical and culinary qualities. When cooking, the Hawaiian-grown rice absorbs more water than does the other, while upon cooling it seems to give up its moisture and becomes more dry and less palatable. There is also a difference in the taste, in the smell, and in the touch of the rice when cooked, and the palatability is greatly in favor of the Japan-grown rice.

CORN.

The work with corn has been more satisfactory during the past season than for three years previous. The rainfall has been heavier, and this has been quite favorable for the corn. In Nuuanu Valley yields were obtained varying from 37 to 60 bushels per acre. It has been demonstrated that at the elevation of the station it is possible to produce corn only from fall or early winter plantings. The yields which have just been mentioned were obtained from corn that was planted in November. Corn that was planted in March was so badly attacked by aphis and leaf hoppers that practically no yields were obtained. Where corn is in small patches and isolated from crops of this kind immunity from attack for the first season may occur, but this immunity is not likely to be continued. At the same time that corn upon the station grounds was suffering from the attacks of these insects a small plat of sweet corn in Nuuanu Valley was not troubled in the least and matured a crop which came off in about the middle of June.

Several different varieties of corn were obtained from the mainland for trial, but because of late planting no definite results were obtained as to which varieties were the better. Small lots of seed of the different varieties were sent to the Kula region of Maui to be tested in the corn district there. The interest in the question of corn cultivation is being increased throughout the islands, and the various ranches are undertaking the cultivation of larger areas in corn for the purpose of supplying feed for their stock during long periods of drought.

It is the intention to erect silos in which to preserve the corn, and it is hoped by means of the silo and of silage to prevent much of the loss which has heretofore occurred during such long periods of drought.

Other crops which are valuable for use in the silos are sorghums, Japanese cane, and the cane tops from the sugar plantations. Experiments will be made also with various legume crops, such as velvet beans, jack beans, cowpeas, soy beans, and alfalfa, in an attempt to improve the quality of silage. Several silos have been completed and others are in process of construction on various ranches and still others are talked of, so that within a few years it is thought there will be quite a number in use in the Territory. Because of the interest in silos and silage crops, two press bulletins were issued, one upon Corn Culture and Improvement,[1] and the other upon Silos, Silage, and Silage Crops for Hawaii.[2]

EXPERIMENTS WITH SMALL GRAINS.

During the year an experiment was made with three varieties of barley and with nine varieties of oats. The varieties of barley were known as Champion Beardless, Oderbrucker, and the ordinary six-rowed bearded barley. The varieties of oats included a white and a red variety obtained from seedsmen in San Francisco, and also the following varieties from the substation at Denton, Tex.: Red Rust Proof, Red Siberian, Red Algerian, Burt, Winter Turf, Ninety Day and Sixty Day oats. This experiment with small grains was very unsatisfactory. The plants furnished an immense amount of green forage, but later in the season a part of this died down, after which the remaining plants threw up seed stems and made a little seed. In each case the heads formed were very short and the seed was very poorly filled out. With the oats not as much seed was obtained as was planted. The barley did a trifle better and yielded about an equal amount to that which was planted. The white oats were earlier and yielded better than the red oats, but were badly attacked by rust. The red oats were uniformly late and remained green to a much later date than did the white. They produced a much smaller amount of seed and were not badly attacked by the rust. It would seem from this test that small grains can not be profitably grown at the elevation of the station, although from time to time volunteer oats at different places seem to make excellent growth.

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[1] Hawaii Sta. Press Bul. 42.

[2] Hawaii Sta. Press Bul. 40.

GRASSES AND FORAGE CROPS.

Tests have been continued with various grasses. Many of the seeds planted failed to grow. Some of those which started failed later on account of lack of moisture. Frequently it happens that the moisture supply is sufficient to start the seed, but the surface dries so rapidly that the supply of moisture is exhausted before the roots are long enough to obtain moisture from the deeper soil. This fact, together with the poor seed, accounts for nearly all failures to obtain a stand with grasses. The new grasses most promising for hay and soiling crops, as a result of this year's test, were Natal redtop, Australian bluegrass, Tunis grass, and Sudan grass. The two latter grasses, of which the Sudan is seemingly the better, have been sent to several ranches for trial. Upon the station grounds they were planted February 20, and 55 days later they had reached a height of 4½ to 5½ feet and had commenced to head out. These grasses are related to and resemble Johnson grass, but are without any underground stem, so that there is no danger of their becoming a pest, as is the case with Johnson grass. They are very palatable, and horses consume even the coarser stems of the grasses. The seed is of good size, heavy, and there is no trouble in securing a stand. How well these grasses will withstand grazing, repeated cutting, or drought, and whether or not they can persist and spread on a range will have to be determined by further trial, but they seem to be excellent for hay purposes. The seeds, if left until all mature, will be molested by birds.

The Natal redtop and Australian bluegrasses are much shorter than the preceding, growing only 24 to 30 inches high. They seed freely within three or four months after planting when not grazed. Not all of the seed, however, is good; with the redtop especially it has been difficult to secure a stand, only 5 per cent or less of the seed being viable. The redtop seed requires some little time for germination, even when good.

The best pasture grasses among those which were tried were doubtless the rescue grass, also known as Australian prairie grass, Texas bluegrass, and one called *Phalaris commutata*, the common name of which is not known. These grasses were planted along with what is here called buffalo grass in a field badly infested with coco grass or, as it is sometimes called, Japanese nut grass. All these grasses seem to be vigorous enough in their growth to overcome the coco grass, holding it in check and making valuable grazing.

Neither the Texas bluegrass nor the *Phalaris commutata* has produced any seed, although planted for 7 months, and they are seemingly best propagated by divisions of the root. The rescue grass, on the other hand, seeds freely, and is easily propagated from seed.

COTTON.

The main field of Caravonica cotton is still in cultivation, the plants being now in their fourth year. The yield in 1912 was very light, owing to the continued dry weather. The spring crop was picked by the middle of July, and there was no further crop, owing to lack of moisture. The spring crop for 1913 has been quite large, and has been picked and the plants were cut back for a later crop.

The work with Egyptian cotton, which was carried on last year at the Honolulu School for Boys, has been given up since the variety does not seem to produce as well as the Caravonica or the Sea Island.

During 1912 the Sea-Island cotton also failed to produce a profitable crop. About one-fifth of an acre was left and the balance was uprooted. A small area on an adjoining field was planted in February, 1913, and this year a comparison will be made between new plants and the ratoon crop from last year's plants. Heretofore the ratoon crop from the Sea-Island cotton has never turned out well, but the present crop seems to be more promising.

The pink bollworm still continues its ravages, and there is little hope of any cotton industry in Hawaii until some remedy has been found for this pest. The cotton areas in the islands are growing less instead of greater. The 50-acre field at Mokaweli, on Kauai, has been uprooted since no profitable crop has been obtained in three seasons, owing to dry conditions and to the bollworm. There remain still on Kauai perhaps 50 acres in cotton, in the Kona region of Hawaii perhaps 75 acres, in the Koneohe district of Oahu about 80 acres, and in the Waianae district possibly 30 acres.

SORGHUMS.

An experiment is under way testing out several varieties of sorghums of African origin received from the United States Department of Agriculture.

With these have been planted two sweet sorghums, Early Amber and Sugar Drip, and also the No. 309 previously mentioned in an annual report as being noteworthy. The latter variety to date leads all of the other 23 varieties.

The No. 309 and Sugar Drip varieties are also planted in a comparative test with Japanese cane to determine which will produce the largest amount of forage within a given time.

SWEET CORN.

With sweet corn some profitable crops were raised. This corn retails at 30 cents per dozen ears, and sells wholesale at 18 to 20 cents. The market demand at times is keen, but usually a small supply stocks the market and then no corn can be sold at any price. The variety grown at the station was very prolific and required 75 to 80 days to reach roasting-ear stage. The ears were usually 6 inches long with 8 rows of broad kernels. This corn was of excellent quality; from catalogue descriptions it might be White Cory. Several plantings were made between November 7 and March 27. Yields were from 533 to 1,436 dozens per acre. At 18 cents per dozen it will be seen that the crop paid well for the short time the land was in use to produce it.

IRISH POTATOES.

Successive plantings of Irish potatoes from November 7 until March 7 show that better yields are obtained by planting at the latter date. The fall planting was attacked by a root-rot fungus, *Rhizoctonia* sp., and by another root or stem rot known as *Sclerotinia rolfsii.* These diseases attacked the plants in the early to medium stages of growth and destroyed them. They are recognized by the wilting or deadening and blackening of the stem from the root to several inches above the surface, killing the plant before any tubers become of proper size. Neither the Burbank nor the Triumph seemed able to withstand them. These fungi are more destructive on early planted potatoes and in wet weather. The later planted crops were not so badly attacked by root rot, but were killed by blight. The Early Rose, Bliss, Triumph, American Wonder, and Burbank were tried later, but none of them could be maintained alive for a period long enough to make good potatoes, even with three sprayings of Bordeaux. One planting which was harvested 98 days after planting commenced to rot within a few days after digging. The early potatoes, Early Rose and Triumph, when left in bags were rotted so badly as to be unsalable. These potatoes were larger and more nearly mature than those of the other two varieties, but seemed to rot more quickly. In this test it was also noticed that there was more loss from rot where the potatoes were left in bags than where spread out in a thin layer on the floor and given ventilation.

Those who have investigated the subject on the mainland advise leaving blighted potatoes undug until two weeks or more after the vines are dead, so that the spores will not get on the potatoes, where they would cause rot. Potato digging there, however, takes place in cooler season, with increasing coolness, while in Hawaii the crop matures in a season which is constantly growing hotter, and if the potatoes are left in the soil great loss will occur from rot. Perhaps, however, frequent rains had washed the spores down on to these potatoes in the soil. In a dry season it may be possible to leave the potato for a longer time, but this year the planting of March 7 was dug on June 16, the potatoes having commenced to rot in the soil.

Experiments with various sized seed pieces were made, but the yield in most cases was determined more by the number of days' growth before blighting than by the seed. Selections were made, but at this altitude it was found impossible to keep them over.

SUBSTATIONS

The two substations with which this department has been directly cooperating are at Waipio, Oahu, and at Kula, Maui.

At the Waipio substation failure is again to be reported, due to lack of moisture. No rains occurred until late in April—too late to help out the crops under trial. On this farm pineapples are being planted to replace the cotton, but several crops have been tried upon small areas. Oats and barley made a poorer crop here than upon the station grounds. Alfalfa seems always to suffer from attack of cutworms; the former area was replanted and an adjoining strip was dynamited and planted, but the resulting stand is very imperfect.

In a long period of drought, such as has prevailed here for over two years past and has but recently been broken, it is hardly worth while to attempt the growing of any ordinary crops, even pineapples being extremely slow to start growth in such dry soil. The failures here include broom corn, Kafir, milo, jack beans, velvet beans, soy beans, pigeon peas, onions, watermelons, and Irish and sweet potatoes.

In Kula some experiments have been started with small grains, corn, sorghums, Japanese sugar cane, Irish potatoes, and various legumes. A resident of this district is authority for the statement that within his sojourn 32 out of 33 crops of potatoes have been greatly reduced in yield from either drought, attacks of cutworms, or blight. The experiments being made this year are principally for control of blight by spraying, but if seed can be preserved from one crop to the next an attempt will be made to improve the crop by selection. Likewise with corn, it is hoped that some improvement may be made by selection and ear-row methods. A silage experiment, carried out in an abandoned cistern, turned out very satisfactorily and has demonstrated to the community at large the value of silage. Experiments are now being made to test out the comparative value of corn, sorghum, Japanese cane, and various legumes for silage.

An attempt at growing winter cover crops has already been made, but as the work did not begin until the first of the present calendar year and partly because of dry conditions, the crops were not large enough to withstand the dust storms and were destroyed.

In the past a wasteful system of farming has been practiced in the Kula corn belt. Following the practices of the farmers in the corn belt of the United States, the corn planters of Kula have been accustomed to take from the fields only the grain. Afterwards what few animals they had were pastured on the cornstalks—then later the stalks and husks were burned, the land plowed, and another crop planted. It was only after such a burning that good clean plowing could be done, and it was desirable to burn the stalks to facilitate the cultivation of the following crop. Gradually this evil practice is being corrected. The stalks only are burned, the husks and leaves being turned under. Some are cutting up the stalks with stalk cutter or cane knives, and turning all trash under. This is the proper method and the only improvements upon this are the use of the silo, as mentioned above, and the use of green-manure crops, which will be explained.

Those familiar with conditions in Kula maintain that the dry summer and fall of 1912 was very exceptional, that ordinarily a fall crop of potatoes is grown, and that other things could be planted. This suggests that cover crops can be grown to advantage with and following corn. All of the crops suggested below can be planted in the corn with a small amount of labor, and some of them require but a small outlay for seed. The benefits to be derived are as follows:

(1) Additional feed for horses, cattle, or hogs.

(2) Prevention of soil washing or leaching during heavy winter rains.

(3) Prevention of at least a part of the blowing of the soil common in early spring.

(4) Improvement of fertility and moisture-holding capacity of the soil by the addition of more vegetable matter as dry or green manure when the land is plowed.

Cover crops may be classified as nonleguminous or leguminous. (1) Nonleguminous crops for pasture or hay and for green manure. The crops best suited for this purpose and the seed of which would be quite inexpensive are the small grains—wheat, rye, oats, and barley. All of these would furnish some grazing during the winter months and could be turned under in time for planting in the spring and would benefit the land as above explained.

There is a small 5-hoe or disk drill costing about $15, made especially for drilling between corn rows. It plants several acres a day and one might suffice for several adjacent small farmers. In the absence of such a drill the grain can be sowed by hand and worked in with single row cultivators or small plows, but the saving in seed by use of the drill would more than pay its cost. Which grain to plant and at what time to plant it are questions which must be worked out by experiment, and some judgment must be used by the planter as conditions in different seasons vary greatly. Probably wheat or rye will be found more suitable for early planting (September or October) and oats or barley for later planting. These may be grazed at times when the soil is dry enough to permit, or they may be cut when still green in the spring for hay. When pastured or cut there is less to turn under for green manure, but it is better to turn under a smaller amount every year than an excessive amount in any one season. If land is prepared for early planting, also, the amount turned under will be less and the benefit of protection from leaching or blowing will necessarily be somewhat reduced in amount.

(2) Leguminous crops for hay, pasture, and green manure. The advantage of these crops over the small grains is that they are able to obtain nitrogen from the air, and to this extent they excel the grain crops for green manuring and improvement of the soil. Not all of them will stand grazing. Many do not so well protect the soil from leaching or blowing, and with all of them the seed is more expensive. Probably the use of these crops will not become common until after the others have been tried and their great value noted.

Cowpeas are one of the most valuable legumes for planting with corn. Throughout all of the Southern States it is now the common practice to sow cowpeas in corn, and usually this is done at the time of the last cultivation or the "laying by" of the corn. They may be sown by hand and covered with the cultivator or may be drilled midway between the rows with the single row corn drill. When this is done another cultivation of corn and peas is usually given. These may be sown in the South, then, from May until August. Enough ripe pods are picked to insure plenty of seed for the succeeding year, after which cattle and hogs may be turned in to harvest the balance. In Hawaii, at lower elevations at least, these may be planted in the fall months, and since parts of Kula are below frost line, no doubt they can be grown there during the winter months. The seed is expensive, but, as stated, seed may be saved from year to year, when a start is once established. Cowpeas are attacked by cutworm and aphis.

Colorado stock pea or Canada field pea can be grown probably only during the cooler months of the year. It is often planted with oats for the "oat and pea" hay crop. Whether or not it will thrive and produce a good seed crop must yet be determined.

Soy beans can be easily grown at any time when there is sufficient moisture to start the seed. Some varieties, however, produce little vine. A coarse growing variety should be obtained, if possible, for green manure.

Peas and beans are of great value as feed and for enrichment of the soil, but of less value as cover crops or for grazing.

The clovers, including crimson, bur, Egyptian, and possibly red clover, are all of great value and do well during the cooler months and the rainy season. They are not suited to hot, dry conditions. Bur clover is much more likely to reseed itself and for this reason should be given a thorough trial. It is also the better for grazing, and less valuable for hay, since it is more prostrate in its habit of growth. Inoculation may be necessary, but the first three named thrive without it on Oahu.

These are the legumes of greatest value for stock feed, but white navy beans, dwarf Lima beans, or other garden beans could be grown after or with the corn crop with profit.

REPORT OF THE ASSISTANT AGRONOMIST.

By C. A. Sahr.

EXPERIMENTS WITH LEGUMINOUS PLANTS.

About two years ago this station issued a bulletin on leguminous crops for Hawaii,[1] in which a report to date was made upon alfalfa, soy beans, cowpeas, pigeon peas, jack beans, and velvet beans. A press bulletin upon peanuts was also issued.[2] Since then more or less attention has been given the various leguminous crops recommended for future trials, keeping an available supply of seed on hand, studying the relative value of different species, when grown under various conditions.

The seed of many new varieties of legumes have been received and tested with varying success, according to their adaptabilities to Hawaiian conditions and general value in rotation. These include soy beans, sword beans, velvet beans, horse beans, asparagus beans, sesbania, kulthi, sunn hemp, stock or field peas, and a variety of Cuban peanut.

To facilitate the selection of leguminous seeds for planting in their relative order of importance for rotation, green manure, forage, hay, and seed crops, the following classification is suggested:

I. Quick rotation, short season, 3 to 4 months:
    Kulthi or horse gram.
    Cowpeas.
    Sunn hemp.
    Mungo beans.
    Soy bean, seed varieties.
II. Medium time, 4½ to 6½ months:
    Soy bean, coarse variety.
    Peanuts.
    Pigeon peas.
    Asparagus bean (sasagi).
    Horse beans.
    Sword bean, early variety.
III. Long period of growth, 7 to 9 months:
    Jack beans.
    Sword beans.
    Velvet beans.
    Sesbania.
    Dolichos lablab.

INOCULATION.

Experiments with artificial cultures of root nodule bacteria were tried with negative results. Plants in untreated soils thrived as well as those in inoculated soil, the number of nodules per plant not lacking in either case.

The sufficient supply of bacteria in Hawaiian soils is probably due to the great number of wild and cultivated legumes found everywhere. Soils known to be devoid of nitrogen-fixing bacteria can easily be inoculated by the application of soil from a nearby inoculated field.

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[1] Hawaii Sta. Bul. 23.

[2] Hawaii Sta. Press Bul. 28.

From 400 to 500 pounds of such soil applied evenly and thinly is ample for 1 acre. Because of the harmful effect of direct sunlight upon the bacteria, soil applied should be harrowed in thoroughly and quickly.

Several artificial cultures are now on the market, any of which might prove valuable for certain legumes.

STIZOLOBIUM PACHYLOBIUM.

Seeds of this species were received from the Hawaiian Sugar Planters' Experiment Station under name of Brazilian velvet bean, but the variety should be called the fleshy-pod bean in order to conform to the classification of the Bureau of Plant Industry.[1] This is the latest Stizolobium introduced in Hawaii. The vines are stout and less erect than any other velvet bean, as was shown in a comparative test with Florida, Mauritius, and Lyon beans. Its rank growth exceeds that of the Lyon bean, which was formerly considered superior to the velvet bean. The vine blooms in 3 to 5 months after sowing, dry conditions tending to hasten the flowering and maturity, resulting in heavier yield of seed but lighter yields of hay or forage, as the leaves shatter and fall before the pod matures. Two trials were made during a long period with almost no rain at all, in light gravelly soils. Both crops matured in about 200 days. The plants took up only a part of the 8-foot space allowed between rows and blossomed at 3 months. At maturity all leaves were gone, only the vines and pods remaining. The pods run 30 to 50 in cluster, are very fleshy when green, with slight gray pubescence. When mature the pods are 3 to 4½ inches long, black, pod valves with two prominent ridges one-fourth inch apart, and several slight secondary ridges. The seeds are large, flattened, mottled gray and brown on white, 6 to 8 seeds in a pod. Under wet conditions the vines remain green and thrifty after pods mature, while but 5 to 8 pods, with 4 to 6 seeds in a pod, make up the cluster.

SWORD AND JACK BEANS.

The Canavali species tried out include No. 655, a Cuban variety, received from Mr. G. P. Wilder, under the name *C. gladiata*; No. 748, received from a local Japanese, under the name *C. incurva*, and five varieties from the Bureau of Plant Industry.

No. 655, *C. gladiata* (sword bean). Vines of very low growth and twining habit. Planted in July, very few flowers set pods, first mature pods late in February, few more by April 15; stems very slender, leaves small, glabrous, flowers reddish purple, pods thick and fleshy, 4 to 7 inches, seeds 6 to 8, dark brown. Plants start too slowly for field cover, but may be useful in covering unsightly walls or fences.

No. 748, *C. gladiata incurva* (sword bean). Like No. 655 in habit; somewhat more spreading and faster growth, flowers waxy white, few blossoms setting pods, blooms late. Two seeds sown November 20, 1912, now producing pods of which none have yet matured. Pods thick, fleshy, 9 inches long, 1½ inches wide, seeds deep scarlet red.

No. 750, *C. gladiata incurva* (sword bean). Seeds received March 17, 1913, from Bureau of Plant Industry, No. 19990, from Japan, sown

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[1] U. S. Dept. Agr., Bur. Plant Indus. Bul. 179.

April 10, 1913, now producing pods. Slow growth at start, becomes rambling vine. Runners very thin and wiry, prostrate, flowers white, pods thick, fleshy, seeds white, distinctly keeled at ends, hilum long.

No. 754, *C. gladiata incurva* (sword bean). Received March, 1913, from Bureau of Plant Industry, No. 19991, from Japan. Planted April 10, 1913, and now producing pods, growth quicker than No. 750, vines prostrate, flowers large, purplish pink, pods recurved with broadened dorsal suture; seeds distinctly keeled at ends and back, elliptical, somewhat flattened, color reddish clay.

No. 755, *C. gladiata incurva* (sword bean). Received March, 1913, from Bureau of Plant Industry, No. 27704, from China. Planted April 10, 1913, leaves somewhat more leathery than No. 754, runners thicker, shorter, not yet in bloom. Seeds large, plump, distinctly keeled, deep red in color. Evidently this variety and Nos. 655 and 748 are late maturing, and may be used as cover crops only in long rotation.

No. 753, *C. ensiformis* (jack bean). Received March, 1913, from Bureau of Plant Industry, No. 21609 from Brazil. This and No. 756, received under No. 01683 from Texas, were planted for varietal test. The vines of each are erect, coarse and stubby, blossoms purple, but vines are not far enough along to note their adaptabilities apart from the jack bean grown by this station for several years past. The feeding of jack-bean fodder to cattle and swine has been attended with varied success in Hawaii, while the feeding value of sword bean has not yet been ascertained. As a cover crop the Indian variety with red seeds and red flowers has proved very satisfactory in Porto Rico. Cattle are said to graze on the plant there to a limited extent.[1]

SUNN HEMP.

No. 575, *Crotalaria juncea* (sunn hemp). Received from the Guam Experiment Station, island of Guam. Stiff shrub 3 to 5 feet high, stock fibrous, leaves linear-oblong, flower bright yellow, large, pods, 1¼ inches long, pubescent, 10 to 15 seeded, grown for hemp in India and Malay Isles.

Tests with sunn hemp carried out in the Philippine Islands in 1907–8 attracted considerable attention because of the prolific seeding habit. One plat measuring 364.5 square meters, planted in rows 0.5 of a meter apart, produced a yield of seed equal to 2,395 kilograms per hectare[2] (2,133 pounds per acre).

> A small quantity of seed was run through a corn-grinding mill and the product screened through a close-meshed wire screen, thus separating the smaller particles, or bean meal, from the larger, or bean hulls. The bean meal constitutes 70 per cent and the been hulls 30 per cent of the total weight. Samples furnished the Bureau of Science showed the following analysis:

Analysis of sunn hemp seed.

Contents.	Meal.	Hulls.	Contents.	Meal.	Hulls.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Moisture	9.66	12.42	Nitrogen-free extract	28.06	54.52
Ash	6.72	4.88	Crude fiber	7.86	17.37
Protein	43.86	9.81	Ether extract	3.84	1.00

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[1] Piper, C. V., U. S. Dept. Agr., Bur. Plant Indus. Circ. 110.
[2] Philippine Agr. Rev., 2 (1909), pp. 25, 26.

Some of the ground seed was fed to stock in small quantities, but tests have not been sufficiently extensive to justify any positive assertions in regard to its possibilities as a stock feed. Horses did not seem to relish it when fed alone, but when mixed with an equal part of oats or Indian crushed feed, they ate it fairly well. Cattle ate the bean meal greedily at first, but seemed to tire of it in two or three feedings. The bean meal was also fed to hogs at various times and was always eaten readily, but owing to a lack of feed in sufficient quantities no systematic feeding tests have been made.

Under Hawaiian conditions the plant made a shorter, more shrubby growth, attaining 3 feet when drilled in rows; broadcasting the seed produced tall, slender plants, 4 to 5 feet high, before setting pods, at the end of 60 days. As the leaves begin to fall shortly after the stand is in full bloom its value as a green manure crop will be materially lessened unless plowed under about the time the stand attains its full flowering stage.

SOY BEAN.

While several new varieties of soy beans (*Glycine hispida*) have been tried out by the station since the publication of the bulletin on leguminous crops for Hawaii,[1] all varieties there recommended were grown further in order to supply the demand for seed. Soy beans were grown more or less extensively by Japanese farmers in Kona, to defray expenses while their coffee trees came into bearing, finding a ready market for culinary purposes and also among local soy sauce brewers. Since the coffee orchards now demand the entire attention of the growers, the soy brewers depend upon soy beans imported from Japan for their supply.

The brewing of Japanese soy sauce having become a well-established industry in Hawaii, a visit of inspection to several of the largest factories was made to ascertain the method of manufacture, which is given here briefly. The soy beans are first boiled in large iron vats, from 4 to 6 hours, then left to cool for 18 hours. The mass is then mixed with an equal amount of California wheat, which has been browned in pans and coarsely ground. The mixture is then poured into molds, and left to stand for three or more days, or until slightly covered by mold fungi. The molds are then emptied into large cedar vats of 500 to 800 gallons capacity; a starter made from cass and brine is then added, and the mass is left to ferment for a period ranging from 6 months to a year or 18 months, the mass being thoroughly stirred twice each day. The fermented mass is then transferred into a large press and the liquid sauce is pressed out, boiled 2 or 3 hours, and put in cedar tubs of 4½ to 6 gallons capacity.

While all manufacturers use equal parts of soy beans and wheat, the density of brine differs in the cheaper and better grades of soy sauce. One manufacturer uses 800 pounds of island salt dissolved in 350 gallons of water to 1,000 pounds of soy beans, producing about 350 gallons of soy sauce when brewed. Another soy brewer uses 500 pounds salt dissolved in 150 gallons of boiling water to 400 pounds of soy beans, producing about 240 gallons of soy sauce and about 600 pounds of cass, or soy leavings. One soy brewer uses 4 bushels of salt dissolved in 200 gallons of water to 500 pounds soy beans, while the brewer of a recently equipped, up-to-date brewery uses 300 pounds of salt dissolved in 200 gallons of water to 600 pounds soy beans, producing 200 gallons of soy sauce and 800 pounds of cass.

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[1] Hawaii Sta. Bul. 23.

The ferment starter is made of a small quantity of soy-bean cake, or cass, sprinkled over a few handfuls of parboiled soy beans and left in a warm place for several days. The cass is sold for 20 cents per 100 pounds to rice planters as fertilizer, and contains about 20 per cent salt. It is also fed to hogs, after soaking in water to draw out the salt. The brewers buy imported soy beans at $72 per ton in Honolulu, wheat at $40, and salt at $10. The tubs in which the soy sauce is put up are made of Japanese cedar, shipped knocked down from Japan, and put together as wanted. The cost per tub is from 40 to 70 cents, according to their capacity, which ranges from 4½ to 6 gallons. Soy sauce is eaten by all classes of Japanese as a table sauce, with their rice, fish, and meats. It has the color of strong black coffee.

Miso, another Japanese table sauce, is brewed from soy beans and rice. The brewed liquid is clear white. The climate of Hawaii is too warm for its manufacture, since the fermentation, like that of "sake" (brewed from rice only), requires a very low temperature, which can not be produced without the aid of refrigerating machinery.

While soy beans do well in Hawaii with but little moisture other than to start growth, success with rank and coarse growing varieties when grown for hay or fodder, is only attained under cool and moist conditions. Thus No. 210 and 211, classed in the above bulletin of the station as late rank-growing varieties, requiring 130 to 150 days to mature under wet conditions, will make a low and shrubby growth and mature in 90 to 100 days under dry conditions. Early varieties, however, mature in 85 to 100 days. Their growth, whether erect or bushy, does not become rank, even though the plant does not immediately die when pods mature under wet conditions, but may live for some time when loss of seed may occur through shattering.

Plate III illustrates No. 635, Otootan, grown from seed received from the College of Hawaii in May, 1911. This variety is undoubtedly the coarsest, rankest growing soy bean ever grown by this station. It is also most tolerant of both dry and wet conditions, but only makes a rank growth during a cool and moist growing period. Under dry conditions this variety makes a spreading, shrubby growth, gaining a height of 2½ to 3 feet, spreading 2 feet upon a side. The yields are prolific, 15 feet of running row yielding 3 pounds of seed, pods maturing in 80 to 90 days after sowing. When growing under wet conditions the growth of this soy bean varies, some of the plants immediately assuming a coarse, viney growth, which after gaining a height of 3½ to 4½ feet become spreading, the vines attaining a length of from 5 to 8 feet, blooming profusely, but setting few pods. Other plants make a thick, erect main stem, 3 to 5 feet high, with 4 to 8 branches, more or less twining, setting 4 to 6 pods in a single axil, maturing late. The flowers are small, purple; pods, 1½ to 1¾ inches long, deep brown; pubescence, tawny; seed, 3 to 4, black, globular. Vines mature in 130 to 150 days in winter. Trials of this variety made at Hilo and Glenwood substations resulted in coarse growing vines, 4 to 6 feet long, attaining a height of 3 to 5 feet, but failed to set pods. Vines can be cured as hay in 2 to 5 days under good conditions. The cured hay, comprising approximately 25 per cent of the green weight, when fed to mules was readily eaten.

The following table shows the relative value of different varieties of soy beans when grown for hay and forage.

Calculated acre yields of soy beans from 20 feet of running row cut for hay and fodder.

Agronomy accession Nos.	Height.	Spread.	Number of days after sowing.	Distance between rows.	Acre yield, green manure or fodder.	Cured as hay.	Yield of seed.	Stage of growth.
	Inches.	*Inches.*		*Feet.*	*Tons.*	*Tons.*	*Pounds.*	
635	33	30	81	2	11.97	2.99	....	First blooms.
635	36	22	90	3	7.26	1.13	....	Full bloom.
635 and cowpeas [1]	30	36	90	3	11.97	2.45	....	Do.
635 only	42	30–60	124	2½	17.04	4.15	....	Last blooms.
211 (S.P.I. 20798)[2]	18	14–16	52	2	5.98	.81	....	Seven days before first blooms.
809 (S.P.I. 19183)	24	20–22	52	2	8.16	1.08	....	Pods half grown.
698	18	17–22	81	2	7.00	1.10	1,960	Pods mature.
483 (S.P.I. 14953)	23	27	81	2	8.16	1.72	....	Pods two-thirds grown.

[1] First pods of cowpeas matured, soy beans still heading out above cowpeas.

[2] Described in Hawaii Sta. Bul. 23. Planted beside No. 809 for comparison.

No. 698, Russian soy bean, was received from S. R. Cope, London. It is a small, erect, shrubby plant, 16 to 19 inches high, spreading 9 to 11 inches; flowers white, very prolific, matures in 80 to 90 days; about 10 per cent of leaves turn yellow in 80 days and 80 per cent fall in 85 days; pods mature in 80 days, slightly shattering.

Seven varieties received from the College of Hawaii were planted in a heavy black clay soil; started well, but failed to grow, owing to severe dry conditions. No other station fields were available for trial planting at the time; however, Nos. 635, 210, and 211 yielded well, but did not make rank growth. Other old varieties grew well, considering conditions that prevailed.

Eight varieties received from the Bureau of Plant Industry, under Nos. 19183, 22379, 32906, 32907, 34857, 34934, 34924 34987, and 34123, were planted, two rows each in a medium clay loam, in May; stands of 80 to 100 per cent resulted from Nos. 19183, 32906, and 32907, the others representing stands of but 10 to 50 per cent.

Four varieties, said to be rich in oil content, were received from an eastern paint and oil company for trial by this station. Samples of these will be analyzed and the oil content determined. The rest of the seed is to be planted as soon as suitable conditions are at hand. Seed of the prospective crop will be analyzed for oil content, in comparison with the original seed.

MISCELLANEOUS LEGUMINOUS PLANTS.

No. 690, kulthi (*Dolichos biflorus*): Received from Bureau of Plant Industry, No. 32657. Small annual suberect vine, grows one-half to 1 foot tall, spreads equally as much, matures in four months, yields at rate of 3½ tons green manure and 1,400 pounds of seed per acre; not recommended when cowpeas are available.

Dolichos lablab: Perennial plant of early introduction to Hawaii. Vine of wild twining habit, growth coarse; flowers in four to five months; flowers reddish white, pods 2 to 4 inches long, seeds black, minutely speckled with red, hilum extended, white. This legume is valuable where a long time intervenes between plantings, and is among those recommended by the Hawaiian Sugar Planters' Station for a cover and green manure crop.

Soy Bean, Otootan, Valuable for Forage and Green Manuring.

No. 727, asparagus bean (*Vigna sesquipedalis*): Received from Hawaiian Sugar Planters' Station under name of sasagi; compact trailing vines, spreading 4 to 6 feet, leaves similar to cowpeas, flowers purple, pods three-fourths to 1¼ feet; first pods mature in 90 days, seeds red, reniform, iris small, black with buff eye. Acre yield not obtained; good cover and green manure crop.

No. 641, Cuban peanut (*Arachis hypogæa*): Seed received by this station from G. P. Wilder, of Honolulu. Plant of trailing habit, with thick stems, requiring mounding or covering with soil at intervals. The pods are long and slender, 2¼ inches long, with very thin shuck. The nuts completely fill cavities, two to three, sometimes four in a pod, although often one end is a pop. Plant very tolerant of rains and drought, prefers light, mellow soil. While the tops are valuable as either hay or fodder, or as green manure, when turned under, the nuts can be disposed of as a money crop.

No. 637, Sesbania: Received from the College of Hawaii, under the name "Sowachen," a tall shrub, 8 to 10 feet high, spreading 4 feet upon a side; central stems and branches fibrous; leaves bipinnate; leaflets 16 to 22; pods ⅛ by 8 inches, beaked with persistent style. Valuable as a green manure crop if turned under when 3 or 4 feet high.

No. 800, Sesbania ("Densei"): Received from Kyoshito, Formosa, under the name *S. ægyptiaca*. While the leaves of *S. ægyptiaca* are described by botanists as 3 to 6 inches long, leaflets 21 to 40, the above "Densei" has leaves 9 to 15 inches and leaflets numbering 44 to 64. Since it was planted late in April, the test has not been carried far enough to ascertain whether or not it will succeed in Hawaii as a green manure crop.

Canada field or stock peas tested out by the station during the past year were a complete failure, owing to severe attack from leaf miners.

Tests with white navy beans gave fairly good results; the vines made a low compact growth, hardly gaining a height of more than 12 or 15 inches; very tolerant of dry conditions, yielding over 26 bushels of seed per acre.

Horse beans, like the stock peas, failed in making successful growth.

While tests with the dwarf Lima bean were not entire failures, the growth they put forth was insufficient to warrant further trial as a cover or green manure crop; however, the plants have very prolific bearing qualities, when conditions favor, bearing continuously for a period of two to three months if the green pods are picked. These can be disposed of as a money crop, selling at 5 cents a pound. While climbing varieties of Lima beans do well under certain conditions, one variety planted among other legumes failed to make successful growth and was discarded.

Mungo bean (*Phaseolus* spp.): Of two varieties of mungo beans tested, one gave good results. No. 582, the Mauritius mungo bean, has vines of semierect habit, 1½ to 2 feet high, spreading 1 foot upon a side. Seventy-five running feet of row yielded 104 pounds green matter, and, when thrashed, yielded 7 pounds of seed. Seeds yellow; should be planted in rows 1½ feet apart for good cover and green manure crop.

No. 634, mungo bean, "Rikutan" variety, with green seeds, low compact growth, matures in same time as No. 583, but yields much less.

REPORT OF THE SUPERINTENDENT OF THE HAWAII SUBSTATIONS.

By F. A. Clowes.

HILO SUBSTATION.

At the end of the last fiscal year the Hilo substation, which had been operated as a cooperative station, was taken over entirely by the experiment station. On account of pressing need for the available funds in other places all the experimental work was discontinued except the banana experiment.

This experiment was planned to study the influence of planting bananas at various distances apart. The varieties used were Bluefields, the banana of commerce, and the Hamakua, a variety resembling the Bluefields, although quite distinct from it. The distinguishing characteristics of the fruits of these varieties do not appear to be clearly recorded. In the last annual report of this station mention was made of some of the distinguishing characters of the plants of the two varieties. In harvesting the fruit of the plants in this experiment it was found that the Hamakua variety is almost entirely devoid of the angular shape so characteristic of the Bluefields. The Hamakua is in shape very similar to the Chinese or Cavendish banana. In ripening also the skin of the Hamakua browns in small spots like the speckling of the Chinese, whereas the Bluefields tends to brown in large patches. The flavor of the Hamakua is mild and sweet, while that of the Bluefields is sharper and more acid. So far as could be observed, there is no difference in shipping qualities of the two varieties. When very ripe the fingers of both varieties fall from the bunch, but not to such an extent as to interfere with either variety being shipped to the mainland market if harvested green and shipped properly. These observations are of value in view of the importance that these two varieties would probably assume in the event of a considerable development of the banana export business in Hawaii.

The average time from planting to harvesting of the first crop of all bunches in this experiment was one year and three and a half months. As soon as the bunches were brought in from the field they were hung in a room 6 by 10 feet, with wire screens at the ceiling, but nevertheless poorly ventilated and very warm during the heat of the day. The average length of time from harvesting to ripening was 14 days.

The following table presents the data of the yields of this first crop. In dividing the bunches into two classes, those weighing over 50 pounds and those weighing under 50 pounds, the idea is to indicate those salable for export and those which would not be acceptable for sale in mainland markets. These figures are not presented as conclusive, and it is possible that the second crop will alter the standing of the various plats of the experiment.

Yield of bananas planted at various distances.

Distance of planting.	Number of bunches per acre over 50 pounds.	Average weight of bunches over 50 pounds.	Total weight of bunches over 50 pounds.	Total weight of bunches under 50 pounds.	Gross weight of bananas per acre.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
8 by 8 feet	242	57	13,867	17,073	30,940
10 by 10 feet	218	59	12,850	8,593	21,443
12 by 12 feet	202	60	12,167	4,486	16,653
15 by 15 feet	137	64	8,783	2,658	11,441

GLENWOOD SUBSTATION.

So many factors combine to influence the growth of crops that in studying the best month of the twelve for planting any given crop only by repeating experiments over a number of years can approximately reliable conclusions be arrived at. This much has been observed, however, as affecting crops in general: With cutworm and similar pests there are certain seasons when they do more harm than at others. While opportunity has not presented itself for thorough entomological studies, it has been noticed that the most severe cutworm damage takes place during the months from December to March, inclusive. After March the greater number of the species seem to be in the pupal stage, and during the months of adult life comparatively little harm is done. It is very apparent, therefore, that for crops like corn, which are so susceptible to injury by cutworms, the safest months for planting are from March or April on till even as late as September. Oats, barley, and similar broadcasted crops seem to be better adapted to the later months, when crops carrying relatively few plants to the acre would be ruined before attaining such a stage as to be free from cutworm injury.

In September the creamery plant mentioned in the last report started operations. Many problems presented themselves in establishing a creamery in this region. The dairymen were greatly scattered, although most of them lived very close to the Hilo Railroad, and their cream was thus cheaply transported to the creamery. Comparatively few lived close enough to the creamery to deliver whole milk. Some who wished to ally themselves with the creamery lived 5 miles from the railroad. Some also who could not deliver whole milk had no separators and had so few cows and were so financially embarassed that the purchase of separators seemed too great a burden. At the end of nine months' operation of the creamery by the experiment station 15 patrons had been secured, who organized themselves into a cooperative association to operate the creamery and took over the creamery plant on June 1. Some of these patrons deliver milk, some deliver separator cream daily, some separator cream on alternate days, some gravity cream on alternate days, and one man living at a great distance, but where he can secure ice readily, delivers semiweekly.

After several months of testing the acidity of the cream delivered, using Farrington's alkaline test, 0.5 per cent of acidity seemed to be the degree of acidity which would be possible of attainment as a standard for first-grade cream. In caring for milk and cream in Hawaii at elevations below 3,000 feet water for cooling purposes is not generally procurable which is cooler than 68° F. The care of cream from delivery at the creamery is therefore a matter requiring considerable attention. In one case home pasteurizing has enabled the patron to deliver cream semiweekly that tested less than 0.5 per cent acidity. As a result of the diffusion of information on the subject of care of cream, the supply has so far improved that a higher standard than the one adopted is possible and will be used.

In making butter from this sour cream difficulty has been experienced in securing good flavor and keeping quality. The practice has been adopted of churning at between 0.5 and 0.6 per cent of acidity, producing a mild-flavored butter, and as it is all sold to the home market for immediate consumption it does not absolutely demand the keeping quality that storage or export butter requires. With the increase in the number of patrons, cream routes can be established and more frequent delivery of cream secured. As those unfamiliar with the best dairy practice adopt more approved methods, further improvement in the supply will be obtained.

A good price is being secured for all the buttermilk produced at the creamery and the demand for cream is increasing. Cooperative buying of feeds is also being done, wholesale prices being secured to patrons.

While the actual cost of manufacture of the butter is very high, the benefits of the enterprise are great. So far the net returns to the patrons have exceeded what they were able to secure by individual effort. They are also sure of producing a grade of butter at the creamery which is sure of a market. The individual struggle to secure a market for an individual brand of butter is done away with and a feeling of security is widespread. On this account there is a growing interest in the dairy industry and there is great promise for its future development.

The Hilo market was very poorly supplied with flowers, although there was a good demand for choice flowers at times. The soil and climate of the country surrounding the substation are well adapted to growing many choice kinds of cut flowers, such as roses, Easter lilies, calla lilies, Shasta daisies, and violets. A few homesteaders were growing flowers for home ornament and in one case for sale. For eight months the substation has acted as the collecting agent for the flowers of these people, consigning them on certain days of the week to a Hilo firm for sale on commission. The sales have increased steadily, and there is now an established business that is a great help to the homesteaders in stimulating the growing of flowers as home beautifiers.

As a result of three separate trials of various standard varieties of corn, both native and varieties commonly grown in the United States, a variety grown on the Parker ranch at Waimea, Hawaii, has demonstrated itself to be the most productive of both ears and fodder of all the varieties tried. While further variety tests will be carried on, this variety has been chosen for the main crop and an effort will be made to select and save seed of it for improvement and further adaptation to local conditions. Three acres of the variety are being planted for silage.

Early Orange sorghum has been chosen as the result of one trial of 10 varieties for the main crop for the silo. It produced the highest yield of fodder and a good crop of seed.

Among the 20 varieties of grasses tried the most promising are Para grass, Italian rye, Natal redtop, *Paspalum dilatatum,* and rescue grass.

A measured plat of Para grass has yielded in five cuttings during 372 days, from June 27, 1912, to July 4, 1913, 70.7 tons of green fodder per acre. Each time the plat was cut it was top dressed with the quantity of manure produced by the animals to which the grass was fed. Para grass is a profitable crop in this region if treated in this way. Italian rye grass grows well from seed, and is a promising grass for pasture and even for soiling purposes. *Paspalum dilatatum,* commonly known locally as water grass or Australian grass, also promises to be a valuable grass for soiling purposes, and possibly for pasture. Natal redtop (*Tricholæna rosea*) also promises well as a soiling crop. Rescue grass would be a help in pasture mixtures.

Large yields of green feed have been secured from oats sown in the months from September to December. Oats sown in January were completely ruined by rust. This crop has given such promise that it is worthy of extended trial. It is not known whether the occasional failures of this crop are preventable by attention to season, variety, or fertility. While barley was in no case the equal of oats in yield, it has escaped injury from rust.

Of the legumes, soy beans and jack beans are the only ones that seem at all promising. None of the clovers has so far made satisfactory growth, although individual plants of several clovers have grown very well.

An organization of professional and amateur poultry keepers was effected through the instrumentality of the substation. This organization deals with matters of mutual interest to the members, such as marketing, purchase of supplies, holding of educational meetings, and an annual poultry show. The association has adopted the name of the Hawaii Poultry Keepers' Association.

During the year the substation has rendered executive assistance to the Hawaii Buttermakers' Association, an organization of dairymen, working along the lines of farmers' institute work.

In January four Guernsey cattle were imported for the substation. A bull, Raymond of Alta Vista 16095; sire, Raymond of Freehold V; dam, Countess Gocotte XIII. The females were heifers, as follows: Kitchener's Vimera 37887; sire, Lord Kitchener, imported; dam, Buttercup of Vimera, imported. Duchin of Upper Freehold 38466; sire, Spots Sun of Upperfreehold; dam, Duchess of Upperfreehold. Hopeful of Upper Freehold 38468; sire Spots Son of Upper Freehold; dam, Hope of Upper Freehold. The bull is standing for service, and is much in demand by the neighboring dairymen.

During the year, by means of demonstrations at the local government school, interest has been aroused in apiculture. As a result, the homesteaders are establishing home apiaries with wild bees from the surrounding forest. A small apiary has been started at the substation.

APR [illegible]

Issued February 20, 1915.

HAWAII AGRICULTURAL EXPERIMENT STATION,
E. V. WILCOX, Special Agent in Charge.

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION.

1914.

UNDER THE SUPERVISION OF
OFFICE OF EXPERIMENT STATIONS,
U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1915.

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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LETTER OF TRANSMITTAL.

Hawaii Agricultural Experiment Station,
Honolulu, Hawaii, July 30, 1914.

Sir: I have the honor to transmit herewith and to recommend for publication a report of the Hawaii Agricultural Experiment Station, 1914.

Respectfully,

E. V. Wilcox,
Special Agent in Charge.

Dr. A. C. True,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. True, *Director.*

Publication authorized.
D. F. Houston,
Secretary of Agriculture.

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REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1914.

SUMMARY OF INVESTIGATIONS.

By E. V. Wilcox, *Special Agent in Charge.*

BUILDINGS AND GROUNDS.

The glass propagation house which was erected for use in propagating delicate cuttings and seeds was originally fitted with a water tank on one side which was covered with glass. This was intended as a sun heater, the water circulating through pipes under the propagation beds and connected with the tank on the outside. It proved unsatisfactory, however, and a rearrangement was made by which a gasoline heater was sunk into the ground alongside of the propagating house. This arrangement has given satisfactory results.

The sedge commonly known as Japanese nut grass (*Cyperus rotundus*) has become generally distributed throughout Hawaii and has proved to be a most difficult weed to eradicate. Several patches of it have become established on the station grounds, in fact it is practically impossible to prevent its accidental introduction through seeds carried by animals or on the shoes of visitors. The remarkable quickness with which the nut grass springs up after hoeing makes it an unusually serious pest in all cultivated fields except in the case of tall crops like cane or pigeon peas which ultimately shade the nut grass out. The apparent destruction of the nut grass by this means, however, is a delusion, for as soon as the crop is harvested the nut grass begins again unabated. The only method by which this pest has been successfully controlled thus far is that of mowing at intervals sufficiently frequent to prevent the weed from forming seeds. If this practice be persisted in for a sufficient length of time, the underground bulbs become exhausted and the plants die. This method, however, is not applicable in cultivated fields. A series of experiments has therefore been devised to test various methods of eradication, such as hoeing, harrowing, cutting, and spraying with arsenite of soda at intervals so timed as to prevent the weed from seeding. It is hoped in this way to find a practical method by which the further spread of nut grass can be prevented.

About 7 acres of land adjoining the station grounds and belonging to the Public Health and Marine Hospital Service were turned over to the station for agricultural use for an indefinite period. Not all of this area has soil adapted to agricultural purposes. The whole tract has been fenced and about 5 acres of land cleared ready for plowing. It may not be possible to put water for irrigation purposes on this land, but the rainfall during the autumn and winter is sufficient for the growth of winter crops of garden vegetables, cereals, and other crops which it is hoped to test out during the coming year.

One of the chief needs of the station at the present time is a tract of uniform soil which can be devoted to permanent plats for experiments with fertilizers and a rational system of rotation. The need of such a set of plats has become more and more urgent. The present location of the station was poorly chosen in so far as prospects for scientific fertilizer tests are concerned. The soil is conspicuously lacking in uniformity. The physical and chemical nature of the soil changes every few rods and the patchiness of the soil on the station grounds as a whole is one of its most obvious features. Outside of pot experiments, the fertilizer experiments of the station have been made on the substations and by cooperative arrangements with pineapple growers who happen to possess large tracts of uniform soil. No matter how smoothly, however, a cooperative experiment may be operated, it suffers from the great disadvantage that it can not be permanent nor extend over a sufficiently long period. A tract of land which would be well adapted to the purposes of permanent fertilizer experiments lies near the town of Wahiawa and within the army reservation of Schofield Barracks. This tract is separated by a gulch from the remainder of the reservation and could, therefore, not be used by the Army for maneuvering. It is hoped that an arrangement may be effected by which the station can secure the use of this land permanently for agricultural purposes. A series of experiments could then be organized and carried on in a systematic manner so that the effects of certain fertilizer applications and certain systems of rotation would be permanently on exhibit as an evidence of the scientific value of the fertilizer experiments undertaken, and of the practical value of the system thus adopted for the use of the surrounding pineapple growers and other farmers. The experiments now in progress on a small tract of land on Wyllie Street, leased by the station, indicate that the results thus far obtained in comparing aeration and nonaeration of the soil between crops of rice are rendered somewhat doubtful by the lack of uniformity of the soil. This tract therefore can not be used for the purpose in question, but must be devoted to other work where uniformity of the soil is not of so much importance.

The growth of the station has brought about the urgent need of another building of about the size and proportions of the present office building. The present office building is needed exclusively for office, library, mailing room, and storage of bulletins. The quarters of the entomologist are at present in the office building. The building in which the departments of agronomy and chemistry are now housed is all needed for the chemical department. The horticultural department occupies a small building not well adapted to the work of the department. A new building of the size of the present office building would furnish room for the departments of agronomy, horticulture, and entomology for a number of years to come.

CHANGES IN THE STAFF.

D. T. Fullaway, at the request of the Bureau of Agriculture of the Philippines, was furloughed for work in connection with that institution from October 15, 1913, to February 28, 1914. He was again furloughed on June 1, 1914, for a period of one year to search for parasites of the Mediterranean fruit fly, under the auspices of the Territorial Board of Agriculture and Forestry. J. E. Higgins was absent on furlough during the whole year for work in connection with the University of Porto Rico. C. K. McClelland resigned to accept a position as agronomist at the Georgia Experiment Station. It is proposed for the present at least to have the assistant agronomist continue the work of that department under the direction of the chemical department in order to affiliate more closely the work along those two lines. A plant pathologist is greatly needed at the station. The funds which have thus far been available were not sufficient to make possible the employment of a man for this purpose. There are a number of plant diseases in Hawaii which need investigation. Prominent among such diseases are a banana disease of unknown nature, anthracnose of mango and avocado, and a blight of potatoes.

SUBSTATIONS.

The problem of greatest importance at the Glenwood substation is that of producing suitable forage and other feeding stuffs for dairy cows. The large tract of land devoted to dairying in the neighborhood of the substation presents some peculiar difficulties which must be overcome. The general peculiarity of the neighborhood is the excessive rainfall, which ranges from 200 to 350 inches per year. Occasionally there are years in which there are not more than 20 days in which heavy rainfall does not occur. Many of the legumes apparently can not be made to thrive under these conditions. The same may be said of certain grasses and other forage plants. It is of course impossible to produce hay under such conditions without an apparatus for artificial drying. The only possible means of storing feed is a silo. A silo has been erected at the substation and a number of experiments have already been made with the different crops for silage. The making of cane silage has offered no more difficulties than are to be met with corn silage, and cane silage of excellent flavor and well liked by cows has been made. The whole sugar cane, including stem and leaves, may be ensiled, or merely the cane tops. No unfavorable fermentation has been found to take place if the silage is properly packed. The acid in sugar-cane silage at the end of three months was found to be only 0.2 per cent. Excellent results were also had with sorghum and Para grass as silage plants. As a soiling crop, honohono (*Commelina nudiflora*) has come into great prominence. This plant grows wild throughout the Glenwood section and ratoons readily, giving heavy crops in succession, particularly if a top-dressing of manure is added from time to time after cutting.

The pure-bred Guernseys purchased for the substation have given a good account of themselves. The registered bull has been much used for service among the cows of neighboring dairymen with the result that there are now 15 grade heifer Guernseys sired by the substation bull.

The creamery work of the Glenwood substation has been reorganized on a slightly different plan from that which prevailed last year. It was found unsatisfactory to ship milk from Hilo and other distant sections to the substation creamery. The cream showed too high a percentage of acid. While the number of cows in the neighborhood is gradually increasing, there are not enough at present to make practicable a cooperative creamery run by the dairymen themselves. The essential features of the association already formed have been retained in the present organization under the title of the Hawaii Butter Makers' Association. Such members of the association as live at too great a distance from the creamery now make their own butter. The milk from the dairies in the immediate vicinity of the substation creamery is separated and butter made for the actual cost of the operation. All of the butter made at the substation creamery and by all other members of the association living at a distance from the creamery is sold by the secretary of the Butter Makers' Association. This butter has made a satisfactory place for itself on the market in Hilo and in Honolulu.

The Glenwood substation is also carrying on experiments with poultry and ducks. A flock of Rhode Island Red chickens is maintained at the station as a general purpose breed, and White Leghorns are raised for egg production. The system of deep litter brooders is used with pronounced success.

At the Hilo substation experiments with bananas and taro have been continued. A study of the varieties of taro of most economic importance has been made and descriptions are being prepared. This material, together with results of experiments in various methods of propagating taro, various distances of planting, and the use of various fertilizers will be ready for publication as a taro bulletin during the coming year.

The work at the Waipio substation is of a cooperative nature. The main problem for the year was a study of onion production. Red and white Bermuda onion seed was planted directly in drills in the fields on September 23, October 3, October 9, November 13, and December 10. Part of the seed was planted in shallow furrows and part in level culture. The Waipio substation is in a region of low rainfall, but unusually heavy rains occurred this year, filling the furrows with soil and burying the onion bulbs. Considerable thinning and transplanting had to be done throughout this area, and the bulbs buried by washed soil had to be uncovered. The best results were obtained from the sowings in September and October. November and December appear to be too late. Areas on which trash was burned not only produced larger onions, but the onions required only 90 to 100 days from seeding to maturity, as compared with 130 to 160 days on areas not burned. It is planned to carry on some experiments to determine whether it may be economical to heat the soil in the rows by means of a crude-oil blast before planting. The area planted to onions was 8 acres. Most of the soil showed 3 per cent manganese by analysis. From seeding to harvest 23 inches of rain fell. The 8 acres of onions yielded 32,210 pounds, not counting the small onions of pickling size.

At the Nahiku substation the most important result obtained during the year was the demonstration that by means of cuttings from heavy yielding trees, a whole plantation of rubber can easily be obtained with a yield approximately that of the most prolific trees. In the experiments carried out in Nahiku, whole trees of *Manihot glaziovii* of known high yield were sawed into cuttings three or four feet long and planted in the wet soil. The cuttings take root and begin growth very promptly, whatever may be the size of the cuttings. Some of them were 5 inches in diameter.

The roselle experiment was continued during the year with the result that higher yields were obtained than had ever been reported for roselle, approximately 17,000 pounds of fresh fruit per acre. A drying plant has been erected for preparing the material promptly for shipment. Two hundred acres of roselle are now growing, and from the present condition of the plants it is to be expected that a large yield will be obtained at the next picking.

A 10-acre fertilizer experiment on Ceara rubber was carried out during the year. The results of this experiment while interesting are not sufficiently pronounced to warrant the conclusion that fertilizers would pay when applied to rubber in the Nahiku district. The best results both in yield of latex and in growth of trees were obtained from the use of superphosphate and potassium sulphate, without the addition of nitrogen in any form. The soils in question are rich in humus and nitrogen.

At the Homestead substation particular attention was given to the relative economy and profits to be obtained from the growing of various crops, including sugar cane, pineapples, peanuts, field corn, and sugar corn. The results obtained indicated that pineapples yielded the greatest profit, followed by sugar cane and sweet corn. The relative economy from these crops, however, varies from year to year on account of the irregularity in prices. At present the prices offered by the canneries for pineapples are less than the cost of production.

COOPERATION WITH MILITARY POSTS.

During the year the amount of cooperation with military posts has greatly increased. For the most part new work in grading and street making at the Army and Navy posts has made it necessary to secure large quantities of ornamental plants and fruit trees in order to overcome the barren appearance of the new grounds. Along this line of work the station staff has furnished plans, general advice, and a large amount of material for planting. At Schofield Barracks a rather elaborate farming experiment is in progress in cooperation with the station. About 60 acres of land have been planted in legumes, Sudan grass, sorghum, Japanese cane, and other forage plants for the purpose of furnishing green feed for Army mules and horses. As a result of the favorable outcome of this experiment it is likely that the authorities at Schofield Barracks will extend their farm operations for the coming year. The United States Army is one of the largest factors in Hawaii in bringing about the greater development of diversified farming. The Army already uses algaroba meal as a part of its mule and horse ration and will take corn as another portion of the ration as soon as it is produced in sufficient quantities. The Army contracts call for 28,000 pounds of onions per month and 240,000 pounds of potatoes per month. During the past year onions were supplied from local sources for two months only, but potatoes not at all. The Army purchased outside of contract large quantities of eggs, poultry, and miscellaneous farm produce. The military authorities are desirous of having the Territory develop a completely independent source of food supply.

MARKETING DIVISION.

At the 1913 session of the Territorial legislature an act was passed providing funds for this station to be used in furthering the marketing of miscellaneous agricultural crops. The Territorial marketing division was established under the supervision of the station on July 1, 1913. The produce sent in by farmers has increased during the year from $84 to nearly $6,000 per month. The total value of produce received and handled by the marketing division during the year amounts to $26,500, at a cost of $2,000.

The effect of the establishment of the marketing division is apparent throughout the Territory in the greatly increased interest in diversified farming. Heretofore most of the ordinary farm produce consumed in the Territory has been imported. There were only a few farmers who were raising miscellaneous produce, and the small quantity of produce which they raised was totally insufficient to furnish a uniform and satisfactory supply. Dealers in Honolulu, therefore, depended upon the mainland supply. Moreover, the price obtained by farmers for their produce was not sufficient to encourage general agriculture. So unsatisfactory a state of affairs had arisen that the most practical question was not how can a crop be grown, but can it be marketed. The chaotic state of the Honolulu market and high freight rates made it impossible for the farmer to raise miscellaneous produce at a profit.

As a result of the establishment of the marketing division various lines of farming have been developed with profitable results. The shipment of produce from all parts of the Territory to one central market insures a large enough quantity of each kind of produce to occupy a place in the market, and also insures a fairly uniform and constant supply. These conditions having been met, the interest shown in local produce by Army posts, hotels, boarding houses, schools, and other institutions, as well as wholesale dealers, has been gratifying.

The effect of the market has been perhaps most noticeable in the poultry industry. Nearly all farmers who have been interested in this line of work have increased their equipment and the size of their flocks and are prepared to be in a position to supply the demand for eggs and poultry in the Honolulu market. The marketing division issues weekly quotation sheets of the prices which have prevailed during the week on all local produce. These sheets are sent to all interested farmers and to the newspapers of the Territory. Blank forms are also sent out to interested farmers on which they can give the market information as to the amount of various crops planted, when planted, and approximately the quantity and probable time of delivery of the crop to the market. This enables the marketing division to arrange for sales of produce in advance and thus facilitate the prompt handling of the crop. A list of breeders of pure-bred stock is kept, by means of which farmers can be placed in communication with such breeders and secure breeding stock when it is desired.

The work of the marketing division for its first year indicates two directions in which further development is needed. A branch office is required in San Francisco to handle shipments of fresh pineapples, bananas, coffee, sweet potatoes, onions, beans, kukui nuts, coconuts, and the surplus of any other produce which may be raised in Hawaii. At present the business of growing pineapples in so far as the small independent growers are concerned is almost hopeless. The cost of producing pineapples ranges from $12 to $15 a ton. The price offered by the canners at present ranges from $5 to $11 per ton for first-grade pineapples and one-half those prices for second grade. The only hope for the small grower, therefore, until these conditions are rectified, is to find a good market for his fresh fruit on the mainland. The business of shipping fresh fruit can not be carried on satisfactorily without organization. It has been tried by the pineapple growers too many times with disastrous results. If all fresh pineapples were shipped under the direction of a central office in San Francisco, as a branch office of the marketing division, it would be easily possible to prevent a regular succession of bare and flooded markets which have characterized the previous condition of pineapple shipments. Similarly with other produce, a branch office of the Territorial marketing division in San Francisco could create and supply a much larger market for local produce than is now in sight.

Another direction in which the work of the marketing division could profitably be extended is in the line of a retail department. If a cooperative store were established in Honolulu, the farmers of the Territory would be glad to furnish their produce to this store through the marketing division in order to secure for themselves a regular sale of their produce at a reasonable profit, and to secure to consumers the possibility of a constant supply of local produce at reasonable prices.

CHEMICAL INVESTIGATIONS.

The effects of heat were studied on twelve different soils of varying types, the soils being heated to 100 and 250° C. and to ignition. On the whole the effect of applying heat to soils was to render plant food compounds and other chemical compounds more soluble. The most important effects of heating soils are apparently included in the processes of flocculation, oxidation, double decomposition, and alteration of soil elements. There was a slight loss of total nitrogen from heating. One of the striking effects was the unusually rapid formation of ammonia after the soil had been heated. Heating soils seems to bring about rapidly the effects which are otherwise obtained more slowly by aeration. It has been noted in the case of all plants with which experiments have been made that growth is much more rapid on heated than on unheated soils.

Further experiments on the fertilization of rice substantiated the results already obtained along this line. In nearly all of the rice soils of Hawaii ammonium sulphate or some form of organic nitrogen seems to be the fertilizer most needed. Poor growth results from the use of nitrate as a source of nitrogen for rice. Experiments to determine the possible effect of aeration of the soil between rice crops indicated some advantage from aeration, but the experiments were inconclusive on account of the lack of soil uniformity in the experimental plats.

The investigation of the nature of nitrogen compounds in the soil has been continued and the subject studied from various standpoints. The results thus far obtained indicate that bacteria cause more rapid decomposition of the diamino acids than of the other groups present in protein. A further study of this subject is being made on pure proteins. The hydrolytic and other decomposition products of proteins will receive further study.

Attention has been devoted also to a study of the physical properties of soils with interesting results. In heavy clay soils all fertilizers used alone or in mixtures at the ordinary rate have been found to check the movement of soil moisture. Sodium nitrate increased the water-holding power of soils and also increased the rate of percolation of the water. Corresponding with this there was a diminution of the capillary rise of moisture. Capillarity was found to be greatest in silty soils, less in sandy soils, and least in heavy clay soils. In all these experiments the increase in the concentration of the fertilizer salts caused a diminution in the capillary movement of water. In ordinary soils all fertilizers diminished the percolation of water through the soils. Lime and magnesia salts checked percolation less than the salts of sodium, potassium, and ammonium. In clay soils chlorids were found to check the flow of water less than sulphates, while the reverse proved to be true in the case of organic soils. In each case the soil which showed greatest capillarity offered the greatest resistance to the percolation of water. It was demonstrated that fertilizers exert physical effects which are perhaps more easily detected and measured than are chemical effects.

In a study of the function of fertilizers in soils it was found that phosphoric acid was fixed to a greater extent than other fertilizers. This fertilizer proved most effective when applied in the most soluble form. While, however, phosphoric acid in soluble form was fixed in the soil to an almost indefinite extent in so far as leaching is concerned, it still remained readily available to plants, as shown by the decided residual effect of phosphoric acid upon three successive crops grown without additional application of phosphoric acid. Ammonia was fixed to a greater extent than potash, but was less firmly held by the soil, and may become available more promptly. Nitrates were not fixed by Hawaiian soils to any appreciable extent. It was found that there was less loss by fixation in the soils when fertilizers were applied singly than when applied in combination. More deflocculation took place, however, when fertilizers were applied singly.

Continued study of the lime-magnesia ratio in Hawaiian soils brought additional evidence that this ratio is not important in itself. It becomes important only when soluble salts are in great excess or when the soil solution is greatly concentrated and the mineral matters out of normal proportion.

Additional evidence has been accumulated that attention to aeration is especially necessary for the proper growth of plants in Hawaiian soils. No nitrification took place without aeration. In soils which have been left fallow for a year or more there was practically no nitrate nitrogen, but nitrification took place rapidly as soon as the soils were thoroughly tilled.

Volatile antiseptics and heat were found to increase ammonification for a period of two weeks. Nitrification then began after about three weeks, and gradually increased to a maximum. Volatile antiseptics in experiments at the station did not kill protozoa, but these organisms were easily killed by heat. The evidence accumulated in soil work at the station is against the possibility of protozoa being connected with nitrification in soils.

Continued pot experiments with various forms of phosphate have demonstrated anew that soluble phosphates do not leach through the soils, but remain permanently available for plant growth. It was also shown that legumes used as green manure greatly increased the availability of rock phosphate.

Analyses were made of all the common tropical fruits in Hawaii. A special study was made of the changes which take place during the ripening of bananas and papayas. A study was also made of the organic phosphorus of rice. This is of particular importance on account of the extensive use of rice as food. The organic phosphorus compound was found to be formed chiefly in the bran or outer layer of the rice grain.

HORTICULTURAL INVESTIGATIONS.

The attempt to establish a strain of papaya with self-fertile flowers and with male trees eliminated has been continued. The results give promise of complete success within two or three more generations of papaya. The examination of 454 trees of the second generation of breeding showed that 95⅓ per cent of these trees are fruit bearing trees with perfect flowers. Two male trees were cut off 3 feet from the ground and when the new branches came out it was found that the sex had been changed and that regular, perfect flowers, each bearing fruit, were developed.

From the orchard records kept at the station interesting data are now available regarding the average age at which budded, inarched and seedling mangoes and avocados have come to bearing.

On account of the prevalence of the Mediterranean fruit fly it was found necessary to bag some of the fruit which was needed for experimental purposes. Ordinary paper bags were used for this purpose and proved to be a cheap and efficient means of protecting the fruit.

The local interest in hibiscus continues unabated. A number of new varieties have been originated at the station since the publication of Bulletin 29. Perhaps the most interesting ones are two yellow-flowered varieties originated by self-pollination from pink varieties and a semidouble white. Many worthy varieties have also been produced by private breeders and the types have been sent to the station for description. The pink cotton bollworm has been found to breed quite freely in the pods of those varieties of hibiscus which form seed.

A nearly spineless cactus, supposed to have been introduced into Hawaii by Don Marin, has been grown at the station for several years. An opportunity offered to test the hardiness of this cactus in comparison with a number of other drought-resisting plants and several varieties of Burbank's cactus. All of these plants were set out on the island of Kahoolawe in an excessively dry region somewhat exposed to wind. At the end of six months the place was visited again when it was found that none of the plants had grown except the Marin cactus which was growing satisfactorily. In the few tests which the station has been able to make, this cactus, under dry conditions, has grown about three times as fast as the Burbank varieties.

AGRONOMICAL INVESTIGATIONS.

A variety of Japanese rice known as Bezembo was obtained from James Armstrong, of Pearl City. This variety yielded about the same as the other varieties of Japanese rice with which the station has experimented, but matured about 10 days earlier. Experiments will be continued under more favorable conditions to determine definitely whether the æration of the soil between rice crops is of benefit or not to the growth of rice.

Year by year tests are carried on with various cereals in order to determine what kinds fit in with the agricultural program of Hawaii and what varieties can be recommended for Hawaiian conditions. At low altitudes wheat seems to offer no promise. Rye, oats, and certain varieties of barley make a more satisfactory growth. There is a tendency in barley, however, to stool excessively without forming seed heads. Considerable difficulty has been experienced in carrying African sorghums to successful seeding. Seed eating birds are so numerous that it is impossible to save the seed on sorghum plats without bagging the heads. The heads, however, do not develop quite normally under bags.

Among the numerous grasses which have been tried at the station, Sudan grass and Giant Bermuda grass have perhaps attracted most attention. Sudan grass grows rapidly and produces a heavy yield wherever it has been tried in Hawaii except at high elevations. The greatest growth of this grass was obtained on Molokai, where it reached a height of 10½ feet in 70 days. It ratoons promptly and satisfactorily wherever it has been tried. Giant Bermuda grows with unusual rapidity and gives promise of being a valuable pasture grass. Teff grass (*Eragrostis abyssinica*) and saltbushes may also be added to the list of promising forage plants.

The prevalence of blight renders potato raising a precarious venture. Experiments have been carried on at the station for two years in an attempt to develop a system of spraying which would control this disease. The results are still unsatisfactory but give promise that the disease may be overcome. Both Bordeaux mixture and lime-sulphur preparations have been used. The life of the vines is somewhat prolonged but not sufficiently to enable the potatoes to mature perfectly. There is need of a careful study of this disease by a trained pathologist.

Buckwheat and flax have given excellent results in growth and appearance of the plants and in yield. Little trouble seems to be experienced in the growth of these plants in Hawaii either from insect pests or diseases or even from soil conditions.

ENTOMOLOGICAL INVESTIGATIONS.

On account of the absence of the entomologist from the station on furlough for a considerable portion of the year the only systematic work in entomology carried on during the year was on tobacco insects and vegetable diseases. Many of these pests had been previously studied in Hawaii or elsewhere, but the life history of each pest was gone over again in detail so far as possible. Recommendations based on practical experience were made concerning the possible means of controlling these pests.

MISCELLANEOUS.

The interest aroused by the work of the station on kukui oil obtained from seeds of *Aleurites triloba* is shown by the requests which have come from the mainland and from various European countries for kukui nuts and oil for commercial use. There seems to be an active demand for this oil. About thirty-five paint and varnish firms have stated that they would like to buy this oil, some of them to the extent of 25,000 barrels a year. There has been considerable local interest in the kukui industry. Preliminary surveys have been made to determine the amount of nuts available, and one small plant was erected for expressing the oil. It was found in this plant that 40 gallons of oil could be obtained from a ton of nuts. This amount agrees closely with the results obtained in the laboratory at the station. A company is now being organized to express the oil. One New York firm is looking into the business with the idea of securing all of the available kukui nuts in the Territory for oil production. On account of the high value of the press cake as a fertilizer, it would seem best for the Territory that the oil be expressed in Honolulu. The press cake would thus be maintained as fertilizer, and a considerable amount saved on shipments made to New York.

The use of algaroba meal, the ground pods of *Prosopis juliflora*, is rapidly spreading throughout the Territory. The business now amounts to about $350,000 a year. The supply of algaroba beans, while larger than was at first anticipated, is not sufficient for local demands. There is no necessity, therefore, for seeking an outside market for this material. Some of the ranchers and dairymen are preparing to put up plants of their own. For this purpose a drier recently devised by G. F. Winter, of Lihue, Kauai, will be used. An ordinary alfalfa meal mill will grind the algaroba beans very satisfactorily after they have been dried. The Army in Hawaii uses algaroba meal as one-quarter of the grain ration for horses and mules. The interest in this feed is generally more active than has heretofore been the case. As a result of this increased interest there is little of the product which is allowed to go to waste. On some of the large estates the right to pick algaroba beans for a period of ten to fifteen years has been secured.

The experiments carried on by this station and elsewhere with arsenite of soda as a chemical spray for the destruction of weeds has brought about the general use of arsenite of soda for destroying weeds on rubber plantations and on many of the ranches. During the past year this spray was tested on many of the sugar plantations with excellent results and with a great saving in the cost of weed destruction. Several other plantations are now preparing to use the remedy extensively. On one large sugar plantation it has been estimated from this year's work that the saving in cost of weeding alone has been about $100,000. In some of this work the formula used by the station has been modified to the extent of using caustic soda in the place of carbonate of soda to combine with the arsenic. The station is carrying on experiments to determine the fate of arsenite of soda in the soil and its possible effect upon nitrification and upon the physical properties of the soil. In pot experiments when arsenite of soda was added to the extent of 0.25 per cent of the soil, it was found to cause a pronounced deflocculation. The amounts used for spraying purposes thus far have showed no effect upon the soil.

In addition to breeding work with papayas the station has investigated the matter of producing papain. It was found that dried papain can be produced at a profit for about $2.50 a pound. Requests have recently been received for 2,000 pounds of the material at that price. A papaya grower on Maui is preparing to produce the material. In experiments at the station it was found that if in the early morning a dozen shallow lengthwise incisions, one-half to three-quarters inch apart, are made in a papaya fruit of good size, enough juice will be obtained to make half an ounce of dry papain. Fruits may be tapped on alternate days five to seven times in all. As soon as the fruit begins to turn yellow the milky juice flows less freely. The tapping wounds heal quickly and the fruit is not injured by tapping; in fact, the flavor appears to be somewhat improved, since a slight bitterness which characterizes the juice is thereby removed. It has been found that the papain is injured if the juice is allowed to come in contact with any metallic substances. The only precautions to be observed are that tapping be done with a glass, bone, or ivory instrument, and that the juice be collected in china or earthenware containers, and promptly dried. From the work along this line at the station it is estimated that papain to the value of $2 can be taken from each tree annually.

The use of dynamite for agricultural purposes, particularly in improving soil conditions continues to increase. The results obtained from dynamiting pineapple plantations at the end of the first picking season are satisfactory. The extended commercial experience indicates that dynamite, to be most effective, should be used when the soil is not too moist. If a charge of dynamite is exploded in a wet subsoil it has a tendency to form a more or less spherical cavity in the soil, packing the soil about the walls of the cavity without shattering the surrounding soil sufficiently. The use of dynamite in lawns is increasing. Many lawns which have stood for years without renovation show poor growth of grass on account of the extreme packing of the soil. Dynamite can be safely used in lawns for loosening the subsoil below and improving drainage.

The station has advocated since its establishment thirteen years ago the general use of legumes for green manuring in all branches of agriculture in Hawaii. Experiments have been carried on continuously with different legumes to learn what species were best adapted to practical use in the Territory. Among the generally cultivated legumes jack beans and lupines have proved most satisfactory. The German lupine has given excellent results at the station and elsewhere. Jack bean has the advantage of being a rapid and vigorous grower, and also of being relatively immune to plant lice and other insects which may check the growth of cowpeas. If the cowpeas were not so highly susceptible to the attack of aphids, it would be the legume to be recommended for green manuring. Under local conditions, however, jack beans or lupines or Mauritius bean must be considered most promising. For several years this station has been experimenting with an introduced leguminous weed known as rattlepod (*Crotalaria saltiana*). This legume is unusually hardy. It thrives in wet or dry districts. It will make a fairly good crop under rainfall of 20 inches and thrives abundantly under a rainfall of 200 inches. The seed will germinate promptly with little attention after scattering broadcast upon the soil. The plant is not useful for feed, but is an excellent green manuring crop. No insects do any harm to the plant except the blue butterfly, which merely reduces the number of pods. The seed of this plant can be readily obtained by offering children 10 cents a pound for it. Some of the independent cane planters, as well as the larger plantations, already have standing offers of 5 to 10 cents a pound for Crotalaria seed to be collected from the roadsides and elsewhere by women and children. The seed can not be obtained through seed dealers, but the supply to be obtained from waste places seems to be adequate for present purposes. The Crotalaria has the advantage over cultivated legumes that the seed may be sown without any previous preparation of the soil and of course without cultivation after seeding. In old cane fields, after the last ratoon crop is removed, the trash may be allowed to remain, as well as all weeds which naturally spring up. In order to increase the amount of plant material in the soil Crotalaria seeds may be scattered among the trash and weeds and even under these conditions the plant will make a satisfactory growth. The demand for jack-bean seed is increasing rapidly. The price offered is 5 cents a pound in ton lots. The supply is quite inadequate, but a number of homesteaders are preparing to grow the seed for neighboring plantations.

As already indicated, legumes are coming into use on sugar plantations to supplement the amount of humus derived from trash. The tendency at present is to abandon the burning of cane trash and to allow all this material to rot on the soil or to plow it under. The results obtained from this economic use of humus material are so apparent that the practice of burning will probably be abandoned altogether within a few years. On several plantations fields which had become the poorest on the whole plantation gave the largest yield during the past year as a result of plowing under humus-forming material, but without applying excessive amounts of commercial fertilizers.

Analyses were made of samples of coffee from coffee cherries uninfested with fruit fly, badly infested with fruit fly, and also from half-ripe cherries taken four or five days before they would be completely ripe. No chemical differences in the composition of the coffee were noted in these different samples. Coffee was prepared for drinking, however, from all the different samples by three different methods, and the coffee was submitted to several persons for their opinion as to the flavor and other qualities of the different samples. All persons to whom the samples were submitted agreed that the sample from infested fruit was slightly insipid and poor in quality, while that from the fruit not quite ripe was pronounced best in flavor. The only explanation which can be suggested at present for this is the fact that the half-ripe fruit comes to the mill in an uninjured condition, while the cherries from ripe and partly infested fruit are nearly all ruptured and in process of fermentation. The fermentation of the whole cherry rapidly develops a putrefactive odor which apparently affects the flavor of the berry injuriously. As a result of these findings coffee growers are picking their fruit a little greener than heretofore, and are thus securing coffee of better flavor and avoiding the excessive infestation of the fruit fly.

A further test was made to determine whether infestation with the fruit fly might cause a loss of weight in coffee. Using the same number of coffee berries from infested and uninfested fruit it was found that the weight of berries from infested fruit immediately after pulping was 5 per cent less than that of berries from uninfested fruit. The first weight was taken after pulping and allowing the parchment to become dry on the outside. Weighings were made from time to time after removing the parchment and silver skin. It was soon observed that the weights of the two lots of berries began to approach each other. When the coffee came to a constant weight and was considered dry the weights of the two lots were the same. It would appear, therefore, that little or no loss of weight in the coffee berry is caused by infestation of the fruit fly.

An unusual amount of damage from rats on the island of Molokai led to a test by the station of the value of a rat virus in destroying this pest. The virus was distributed about a year ago. Dead rats were found within a week or two near all the points at which the virus was distributed and have been found whenever search was made up to the present time. Apparently the infection has persisted for a whole year with the result that the number of rats has been reduced about one-half. No evidence has appeared that this disease which persists among rats can infest other animals.

Experiments are now in progress to determine the applicability of cold storage to various tropical fruits. It has already been found that holding fruit infested with the fruit fly for a period of ten days at a temperature of 32° F. destroys the fruit fly in whatever stage it may be present. Perhaps cold storage will be accepted as a sufficient means of rendering fruit such as avocados safe for importation into the United States. It has been demonstrated that avocados may be held without injury to the fruit at a temperature of 32° F. for at least two months. The same has been found to be true for star apples and water lemons. Figs have been held for one month at 32° F. with beneficial results to texture and flavor of the fruit. Pineapples came out of a month of cold storage at 32° F. with excellent flavor. The only fruits which have thus far shown a tendency to absorb a disagreeable cold-storage flavor are papayas and mangoes.

Frequent attempts to produce alfalfa hay in Hawaii have yielded rather unsatisfactory results. It seems impossible to secure a good quality of hay. Usually, alfalfa can not be dried in the open air in Hawaii so that it will not heat and mildew when stored. Plans are now being made to dry alfalfa by the devices which are already used for drying algaroba beans. A test of one of these machines on a small scale produced an excellent quality of alfalfa hay which was later ground into meal. The meal was greener and less bleached than the ordinary alfalfa meal imported from the mainland.

A disease of bananas has been observed in Hawaii for many years and has sometimes been mistaken for the Panama disease. It, however, obviously differs from the Panama disease. Infested leaves show spores of a Fusarium, and at the border line between healthy and diseased tissue a bacterial organism was found by Dr. H. L. Lyon in nearly pure cultures. The most obvious symptom of this disease is the death and decay of the terminal young leaves or at least a yellowing and wrinkling of these leaves. Infected plants do not produce the ordinary large leaves, but narrow, yellow, wrinkled ones. Small distorted bunches of fruit may also be formed. These bunches do not fill out properly. It has been found that where the disease is neglected it may gradually become more serious and infect a large percentage of the plants on a given plantation. Spraying with fungicides appears not to be effective, since the fungus is already within the tissues of the plant before the disease can be detected by its symptoms. If, however, diseased plants are cut out and destroyed by fire as soon as they are noticed the disease can be cheaply and effectively held under control. The disease in question seems to affect chiefly the Chinese banana.

During the past year the hen flea (*Sarcopsylla gallinacea*) appeared in Honolulu and has been spreading rapidly. It is found on chickens, rats, cats, and perhaps other animals, and a bad infestation may kill the young chickens. The fleas are similar to the dog flea and have the habit of burying their heads in the skin of young chickens about the eyes and neck and under the wings, where they remain attached like ticks. A number of remedies were tested in attempts to destroy this pest of young chickens. The remedies included carbolated vaselin, containing 2 per cent of carbolic acid; kerosene; zenoleum in a 3 per cent solution, and carbolic acid in 1, 2, and 3 per cent solutions in glycerin and water. The remedies were applied to the heads of young chickens by means of a small brush. The hen flea is evidently very resistant to contact insecticides. About 75 per cent of the fleas were killed with a single application of kerosene. All of the fleas were killed by an application of carbolated vaselin and a 3 per cent solution of carbolic acid. Zenoleum in a 3 per cent solution was about as effective as kerosene. The pest is found in the soil about infested yards and in cracks of buildings. The trouble is so serious that poultry raisers should thoroughly spray infested yards. Since rats may also carry these fleas, this constitutes one more good reason for a warfare on rats.

During the year the following publications were issued by the station:

Annual Report for 1913.
Bulletin 29, Ornamental Hibiscus in Hawaii.
Bulletin 30, The Effect of Heat on Hawaiian Soils.
Bulletin 31, Rice Soils of Hawaii.
Bulletin 32, The Papaya in Hawaii.
Bulletin 33, The Organic Nitrogen of Hawaiian Soils.
Bulletin 34, Tobacco Insects in Hawaii.
Press Bulletin 45, An Experiment in Marketing under Territorial Auspices.
Press Bulletin 46, Poultry Management.

REPORT OF THE CHEMICAL DEPARTMENT.

By W. P. Kelley.

The work of the chemical department has been continued along the lines mentioned in the last report. The great importance of soils and the many practical difficulties and great expense now incurred in their management and fertilization are sufficient reasons for devoting much study to this subject. The efforts of this department, as in previous years, have, therefore, been devoted mainly to soil investigations. In view of the limited state of knowledge concerning soils and the fundamental importance of the subject, it has been deemed wise to devote considerable time to the investigation of problems of a scientific rather than of a practical nature. In this work effort is being made to find the reason for some of the soil processes that are now only imperfectly understood and to render the common soil practices more intelligible. In this connection studies were undertaken on the bacterial processes of soils, on the physical effects of fertilizers and other chemical substances, and on the availability of phosphates. In addition, a study on the composition of tropical fruits in the islands has been completed, and at present an investigation of the organic phosphorus of rice is being made. A limited amount of time has been devoted to miscellaneous analyses.

BACTERIOLOGICAL INVESTIGATIONS.

The availability of nitrogen in soils is of great importance. There are many forms of nitrogen in soils which previous investigations have shown to be available to plants. Most of these arise from vegetable proteins by the action of bacteria, and are susceptible of further decomposition. Usually investigations on this subject have dealt with ammonification, nitrification, denitrification, and nitrogen fixation, without giving much consideration to the intermediate changes between the complex proteins and the end products. However, since different organic nitrogenous fertilizers become decomposed and converted into ammonia and nitrate at different rates, and in view of the fact that different proteins yield different amounts of hydrolytic products which are of unequal availability and which probably undergo further decomposition at different rates, it is a matter of interest to follow the course of the changes taking place.

The initial decomposition may be assumed to be of a hydrolytic nature and probably to result from the action of bacterial enzyms, but whether *deamidization* is a hydrolytic or oxidative process remains to be determined. From previous work on the organic nitrogen of Hawaiian soils it was suggested that bacteria cause a more rapid decomposition of the diamino acids than of the other groups present in proteins. Extending these investigations to include a study of the bacterial decomposition of nitrogenous fertilizers, it has been found that the basic nitrogen compounds (diamino acids) actually disappear more rapidly than the other groups. The work is being continued with the use of pure proteins.

Closely related to the hydrolytic decomposition of proteins in soils is the ammonification of the hydrolytic products. Investigations will be undertaken on the ammonification of the more common amino acids and acid amids of protein cleavage. In this work special study will be given to the amino acids as sources of energy to bacteria as well as to determine the ammonia formed.

PHYSICAL STUDIES.

Evidence has been accumulated in recent years on the importance of physical factors in soils. From the work in this laboratory and the experience of farmers it is certain that physical factors play a very large part in Hawaiian soils. Soil films and colloids especially appear to play an unusually prominent rôle in their fertility. The striking effects of heat on the growth of plants, the high power for absorbing fertilizers, the importance of aeration, the abnormal effects of lime, and the influence of volatile antiseptics, all seem to be related to colloids. The data already obtained in studies on these subjects emphasize the need for much further study along these lines.

As bearing on these subjects, an extensive series of experiments has been carried out on the moisture relations in soils as affected by fertilizers. Such phenomena as capillarity, percolation, flocculation, cohesion, specific gravity, vapor pressure, and hygroscopic moisture have been studied and an unusually large array of data obtained. A number of different soil types were used and very striking results obtained. It has been conclusively demonstrated that fertilizers do exert measurable physical effects and that there are physical pecularities in Hawaiian soils not hitherto met with. In general, it may be said that no two of the different soils studied were affected to the same degree, and frequently not even in the same order, by a given fertilizer.

The results obtained still leave the subject in an uncertain state. The data must be considered to be empirical, and the conclusion drawn as tentative only. Nevertheless, progress has been made.

The subject is one of unusual complexity and will require the patient efforts of years for its elucidation. However, the conclusion seems to be justified that film pressure and colloids are very important phases of Hawaiian soils, and are affected by fertilizers in some instances to a striking degree. The results of this investigation are being prepared for publication by Mr. McGeorge, assistant chemist.

THE AVAILABILITY OF PHOSPHATES.

Experiments have been in progress for more than a year on the availability of phosphates. This work was undertaken in cooperation with the basic slag committee of the Association of Official Agricultural Chemists, but in view of the practical interest in the subject, the work is being extended to include a wide range of phosphates, using a number of soil types and crops. Hawaiian soils contain abnormal amounts of iron and alumina and are able to absorb unusual quantities of soluble phosphates. Consequently, the availability of phosphates is a question of special interest.

The results to date show that different crops vary greatly in regard to the effects produced by different phosphates. Immediately following the application, different soluble phosphates seemed to affect the growth of millet similarly, while insoluble forms were ineffective. After remaining in the soil some months in conjunction with decaying organic matter, however, rock phosphate became as effective as soluble phosphates, and both forms then gave marked increases in growth. In this work such questions as the reversion of soluble phosphates by lime, the lasting effects of phosphates, the absorption of phosphate by the plant, and the effects of decaying organic matter on availability are being studied.

THE COMPOSITION OF HAWAIIAN FRUITS.

The composition of tropical fruits is a subject of much interest. A number of analyses of such fruit have previously been made, but frequently of fruits that had been shipped over long distances after having been picked. With few exceptions, there are no records of the composition of Hawaiian fruits. Therefore, it was deemed wise to analyze the fruits growing in the islands. In this work the different fruits were allowed to ripen thoroughly on the tree, and were analyzed immediately after picking. The results obtained are therefore of special interest as showing the composition of a large number of normally ripened fruits. A study of the changes taking place during the ripening of bananas and papayas was also made. The results are given elsewhere (see p. 73).

THE ORGANIC PHOSPHORUS OF RICE.

The mineral constituents of foods and feeds are coming to be more seriously considered in nutrition. Among these constituents phosphorus is of especial interest. This element has long been known to occur in plants in both organic and inorganic combinations, but the specific phosphorus compound occurring is a matter of uncertainty. Aside from lecithin and inorganic phosphates, very little until recently was definitely known. From the work carried out at the New York State station and elsewhere, it appears that wheat, oats, corn, and cottonseed meal contain rather large amounts of phytin. In view of the great importance of rice as a food, a study of the forms of phosphorus contained in it is of special interest. This work was undertaken near the close of the year, but interesting results have already been obtained.

REPORT OF THE ACTING HORTICULTURIST.

By C. J. Hunn.

J. E. Higgins, the horticulturist of the station, was away during the past year on leave of absence. V. S. Holt and the writer carried on the work as outlined at the beginning of the last year, and attempted but few new lines.

PAPAYA INVESTIGATIONS.

This station has received during the past two years seeds of many varieties of papaya, *Carica papaya*. These seeds have been planted and many of the seedlings are growing at the station. Others have been distributed among private individuals. In the latter case, the station reserves the right to select the best trees and to propagate from these superior varieties. Many of these trees are now coming into bearing.

Mr. Holt has presented elsewhere [1] a more complete report of the types of papaya flowers and fruits found in the F_2 generation of No. 3198, which were grown from two hermaphrodite flowers fertilized with their own pollen. At the time the report was written only 343 trees were old enough to exhibit sex and fruiting characteristics. There are now 454 trees which show the following types:

Types of papayas grown from close fertilized fruits.

Form No.	Character of fruit.	Number of trees.
1	Pistillate	164
1 and 7	Pistillate and pentandria	1
1, 4, and 9	Pistillate, elongata, and intermediate	2
1, 4, and 7	Pistillate, elongata, and pentandria	2
4	Elongata	108
4 and 9	Elongata and intermediate	2
7	Pentandria	1
8	Pentandria and elongata	148
7, 4, and 9	Pentandria, elongata, and intermediate	5
9	Intermediate	0
2	Staminate	16
3	Correæ	5
	Total number of trees	454

The main object in the breeding and selection of this type of papaya is the elimination of the staminate plants. These 454 trees may be grouped as follows:

	Per cent.
Fruit bearing, exclusive of correæ	95. 37
Correæ	1. 1
Staminate (sterile)	3. 52

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[1] Hawaii Sta. Bul. 32, pp. 34, 35.

Since with the diœcious type of papaya, one theoretically expects 50 per cent fruit bearing, the attainment of over 95⅓ per cent fruit bearing, exclusive of correæ, is a great step in the elimination of the staminate type.

Contrary to expectations, the elongata type has increased in percentage, which gives promise of the ultimate development of a pure strain of uniformly cylindrical fruits. Since this type exhibits general uniformity and is of excellent quality, the work in the future will deal strictly with the elongata type and with the elimination of all the other types of flowers and fruit.

CHANGE OF SEX IN THE PAPAYA.

As noted in a previous publication,[1] the forms of the papaya tend to be variable. The staminate flower of the male trees possesses an undeveloped or abortive pistil. Several authenticated cases of the complete change of a male tree to one purely female have been presented in scientific publications. Previous to this time the station has been unable to present favorable evidence on this point from experiments actually performed in the station's orchards. Early last summer Mr. Holt removed the tops of 22 sterile staminate trees. These trees all made considerable growth and now show the following characteristics: Sterile staminate, 18; correæ, 2; pistillate, 1; and elongata, 1.

The large percentage of sterile staminate trees may be due to the fact that the larger number were of the type of papaya which, under normal conditions, produces equal numbers of staminate and of fruit-bearing trees.

The two staminate trees that changed to correæ appeared in variety No. 2978, in which there are 56.25 per cent pistillate, 12.50 per cent correæ, and 31.25 per cent sterile staminate. The two trees that made the complete change in sex from sterile staminate to one pistillate (see Pl. I, fig. 1) and one elongata, appeared in the F_2 generation of No. 2355:1, in which there are 95.37 per cent fruit bearing and only 3.5 per cent sterile staminate. The two trees that changed sex were the only trees of this type that had been beheaded. As has been noted,[1] there are several possible hypotheses which may account for this change. At present, the only possible explanation of these changes in sex is that there is a preponderant tendency to fruit bearing in No. 3198 and a like tendency to the correæ form in No. 2978.

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[1] Hawaii Sta. Bul. 32, pp. 25-27.

MANGOES AND AVOCADOS.

The mango and avocado orchards have been gradually coming into bearing during the past several years. Figures on the bearing age of the various types of trees are as follows:

Bearing age of mango and avocado trees.

	Number of trees.	Average age at time of bearing.		Number of trees.	Average age at time of bearing.
Mangoes:			Avocados:		
Seedlings	48	6 yrs. 3 mo.	Seedlings	27	7 yrs.
Budded	15	3 yrs. 8 mo.	Budded	11	2 yrs. 11 mo.
Inarched	11	2 yrs. 10 mo.			

BAGGING OF FRUIT.

Since the advent into these islands of the Mediterranean fruit fly (*Ceratitis capitata*) many kinds of fruit, on approaching maturity, have been covered with heavy paper bags (Pl. I, fig. 2). The larvæ of *Amorbia emigratella* and of *Cryptoblabes aliena* cause considerable trouble by weaving their webs among the terminal leaves and the flowering panicles of the mango. In order to secure the best fruit it is necessary to remove such webs, as well as diseased and misshapen fruit. While performing these operations but little additional effort is required to place and tie a bag over each fruit cluster. The individual fruits ripen more uniformly but lack the color of those exposed to the sun. Several varieties of the Indian mango have been found to be practically immune to the attacks of the fruit fly.

HIBISCUS.

This station participated in the hibiscus show held during the Mid-Pacific Carnival Week in February, at which time the station's exhibit of varieties, which consisted of Mr. Holt's personal collection of imported and original varieties and those which he has since originated, was unanimously granted the first award. This recognition of the station's collection has created a demand which has been filled in part by the distribution of over 30,000 cuttings and seedlings during the past three months. Mr. Holt has selected the best varieties of hibiscus, and some 200 grafted plants are now being grown in soy tubs for exhibition purposes.

Mr. Holt has outlined a number of experiments in the breeding of hibiscus, one of which is worthy of mention. Yellow hibiscus are exceedingly rare. The process of crossing adopted by Mr. Holt has given a clue as to how this color may be developed. A single orange hibiscus with upright stigmas (39:1) was introduced several years ago from Germany. The F_1 generation (145:1) was self-fertilized and produced a flower much like its parent. This F_1 hybrid was crossed with 1E (533:1),[1] a single pale cerise flower with white veins and throat and a pale yellow column. The resulting cross, F_2 (102:2), has pale crimson petals with light veins, a dark crimson eye and upright stigmas. The F_2 cross was self-fertilized to produce F_3 (395:1) V. S. H. Parents 1E×Single orange (upright).

The new variety may be described as follows:

Moderate growth, freely branching, brownish bark, green twigs, good foliage.

Leaves ovate, acuminate, serrate, nearly smooth, dark green, 1½–2 inches wide, 2¾–3½ inches long, petiole ¾–1 inch long.

Flower 5 inches wide, scarlet orange with yellow veins, crimson eye, column yellow, crimson at the base, stigmas crimson, appressed, peduncle 2 inches long, bracts 6, green, not spreading, self-seeder.

This hybrid, No. 395:1, has been self-fertilized and also used as the male or as the female parent in a large number of crosses, the seedlings of which will be grafted on thrifty stocks to hasten their flowering.

NEW PLANTS.

A number of years ago the station collected in Honolulu several slabs of an almost spineless cactus. Dr. W. T. Brigham states that he has known this cactus for a long time and that he believes it was introduced by Don Marin. Dr. Brigham suggests that this cactus be called "The Manini Cactus" (the Hawaiian form of Marin). These cactus slabs were grown into plants, which after subsequent subdivision have developed into a hedge nearly 100 feet long. A description of the plant is given herewith:

OPUNTIA.—Plant averaging 6 to 8 feet in height, shrubby and much branched; basal slabs forming the trunk, averaging 10–14 inches long, 5–6 inches wide, 1¾–2¼ inches thick, joints 2–2½ inches in diameter, smooth and deep green in color, becoming rough and grayish at the joints; mature slabs 10–14 inches long, 4–5 inches wide, ⅜–1 inch thick, narrowing slightly toward the center of the slab, obovate in form, olive green, and inclined to be slightly woody; immature slabs 8–10 inches long, 3–3½ inches wide, ¼–⅜ inch thick, obovate, pea green, and very fleshy; spines absent or at times small and inconspicuous; after being developed into short fleshy leaves, sometimes with spiny terminals, these appendages fall as the slabs mature; when present these spines are two in number, $\frac{3}{32}$ inch long, light gray below, brownish at the tips; spinules absent or very small and basal, 2 to 3, grayish; spinules are numerous and very small in areoles on the fruit; flowers are borne singly at the tips of young branches and consist of a modified joint, bearing at the apex the floral portions, the ovary being buried in a slight depression in the joint; basal joint 1½ inches long, ⅞–1 inch wide, pear-shaped to globose, green, areoles bearing numerous small spicules, floral portion 1½ inches long, 1¼ inches wide, never spreading; petals averaging 25, outer ones short and fleshy, inner ones long and thin, rose to pink in color; stamens and filaments averaging about 300, filaments 1¾–2 inches long, yellowish at the base, carmine above; stigma and style green, stigma 7 parted; style 2 inches long; ovules numerous and contained in the fleshy fruit; the joint changes to a succulent and juicy fruit,

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[1] Hawaii Sta. Bul. 29, p. 42.

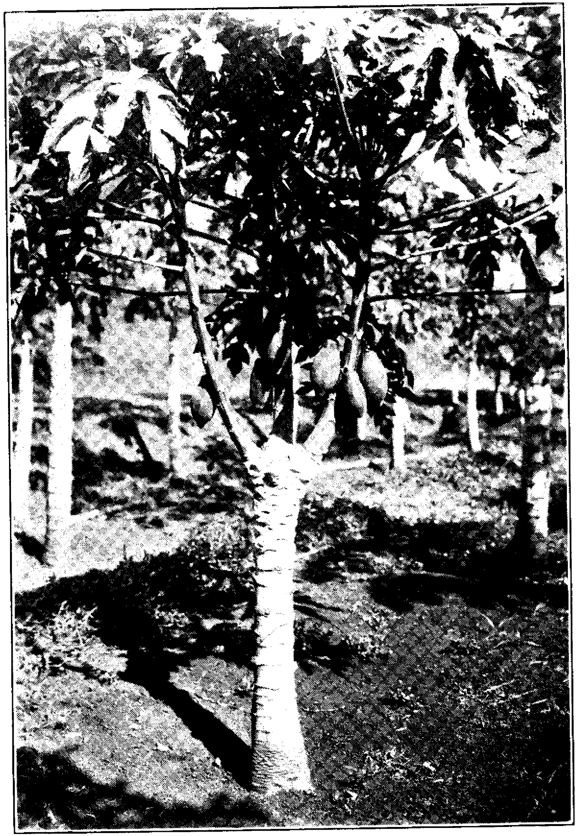

FIG. 1.—STERILE STAMINATE PAPAYA TREE CHANGED TO PISTILLATE BY BEHEADING.

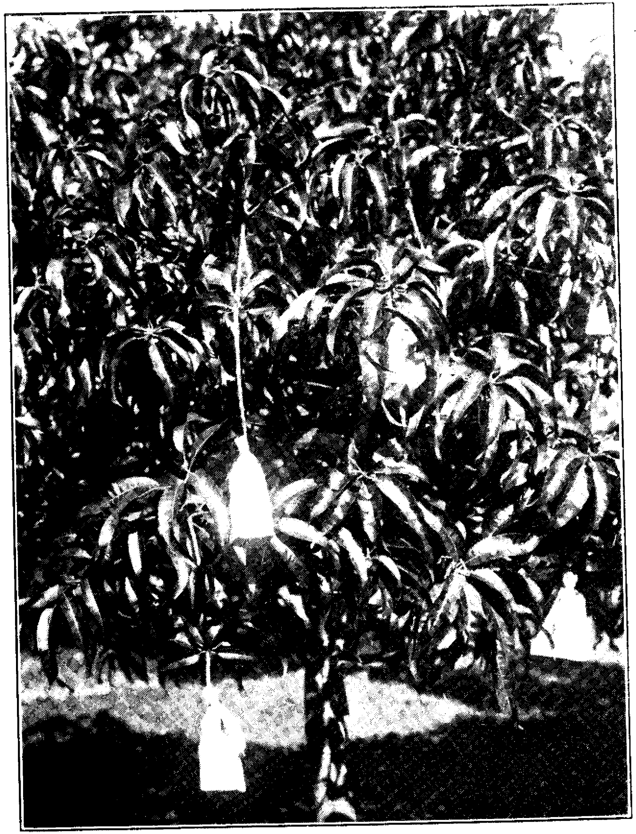

FIG. 2.—MANGO, SHOWING FRUITS COVERED WITH PAPER BAGS.

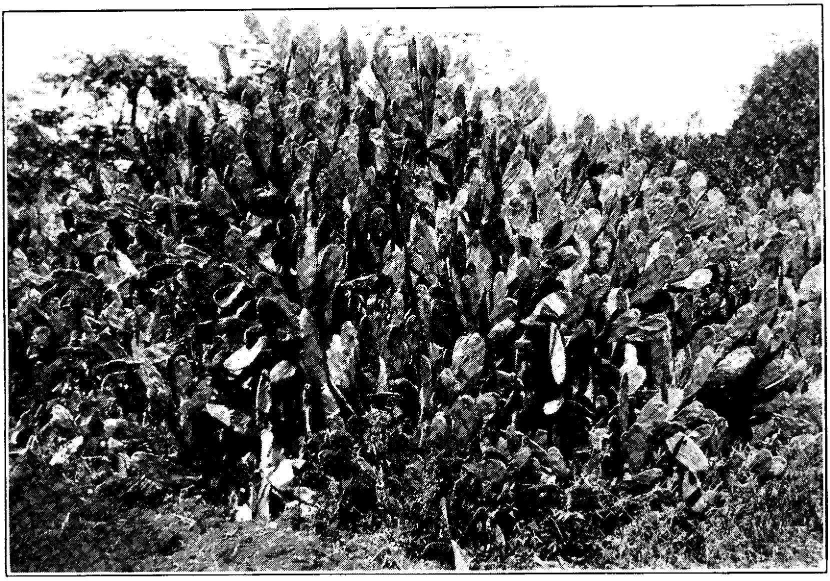

FIG. 1.—OPUNTIA, AN ALMOST SPINELESS CACTUS.

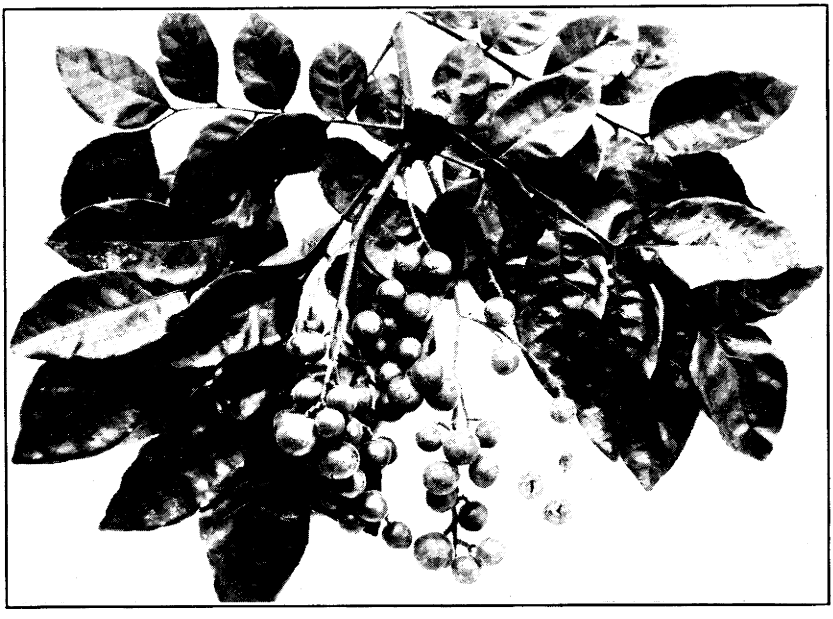

FIG. 2.—CLAUSENA LANSIUM, WAMPI.

1½–2 inches long, 1–1½ inches wide, pear-shaped to globose, areoles with numerous small spicules, claret red; pulp deep claret red, many seeds, watery and almost tasteless.

Rapid growth, very productive, and best propagated from slab cuttings, since seed are liable to be cross-fertilized with the spiny Opuntias.

Since this cactus is of rapid growth and comparatively free of spines, it is worthy of attention as an ornamental hedge and as a fodder plant. (Pl. II, fig. 1.)

One of the little-known fruit plants introduced from China is the wampee, whose edible berries are highly esteemed by the Chinese and others. There are about a dozen trees in bearing in Honolulu.

Clausena lansium; C. wampa or *Cookia punctata.* Wampee or wampi. Aurantiaceæ. (Pl. II, fig. 2).—A small tree, 18–20 feet, with luxuriant foliage, native of South China; nearly glabrous pinnate leaves; small dense panicles of whitish sweet-scented flowers, produced in April; fruit ripens in June and July; an edible berry, borne in clusters like the grape, individual fruit nearly globose, the size of a large marble, rough, tough, orangelike rind pale straw yellow in color and covered with glands full of green balsamic oil; seeds 1 to 3 nearly filling the fruit cavity; a small quantity of almost colorless juicy pulp between the seeds and the rind, with an agreeable, aromatic acid taste.

Propagated by seeds and layers. Often used as a dessert fruit, but mostly for preserves. The leaves are used in flavoring. This fruit is subject to the attacks of the fruit fly and should be covered with paper bags.

THE PINEAPPLE SEEDLINGS.

The pineapple seedlings Nos. 3059 and 3060,[1] were transplanted last October from quart tins into 12-inch flower pots. Since the pineapple plant is greatly influenced by the physical character of the soil, considerable black sand was incorporated into the soil mixture. There were 48 plants in lot No. 3059, of which 31 plants are now growing. These plants vary from 1 to 8 inches in height and from 1½ to 14 inches in the spread of the foliage. In character they may be listed as excellent 1, fine 5, good 8, fair 8, poor 8, and very poor 1; no spines 4, very few spines 11, few spines 5, and very spiny 11. There were 53 plants in lot No. 3060 of which 41 plants are growing. These plants vary from 1½ to 12 inches in height and from 2 to 23 inches in the spread of the foliage. In character these plants may be listed as excellent 6, fine 8, good 9, fair 10, poor 5, and very poor 3; no spines 8, very few spines 13, few spines 1, and very spiny 19. In color the leaves of these seedlings vary from green to red and bronze, either as a solid color or in stripes. A number of these seedlings give promise of developing into superior plants and will later be planted under field conditions in order that the character of fruit may be ascertained.

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[1] Hawaii Sta. Rpt. 1913, p. 23.

THE PROPAGATION HOUSE.

The solar heater which was originally installed in the propagation house when the latter was reconstructed proved satisfactory only during the afternoons of sunny days. A small gas heater and a water boiler were placed in the propagation house. The hot water did not circulate as rapidly as desired and the benefits were not commensurate with the amount of gas consumed. The plan of having the hot-water pipes in direct contact with the sand also proved unsatisfactory because the sand acted as a nonconductor of heat. The water pipes have been placed in an inclosed chamber just below the sand bed. A concrete pit has been constructed at one side of the propagation house, inside of which has been installed a large gas heater, thermostat, and a boiler. Other appliances, such as water, gas, and safety valves and an auxiliary water container, have been placed in position. Preliminary experiments have proved that this arrangement is efficient, but further work is necessary before definite conclusions may be drawn.

FIELD WORK.

The usual field work of this department has occupied considerable time. The various orchards have been pruned, fumigated, and given general cultural attention. Cover crops were sown at the proper season and were later turned under to maintain the fertility of the land.

ACCESSIONS.

Among the accessions of the past year which are worthy of note are several species and a number of varieties of papaya; budwood of selected local and California varieties of avocado; budwood of the Carabao and Pahutan mangoes; a variety of cucumber with a thick, almost reticulated rind, which is said to be somewhat resistant to insect pests; a species of pipe gourd; a collection of 12 varieties of spineless cactus; several new varieties of sweet potatoes; two new varieties of roselle; and plants of *Lansium domesticum* and three varieties of Garcinia.

This station receives frequent requests for assistance in the selection of agricultural materials. In order to be prepared for such demands, there has been gathered together an excellent collection of American and foreign seed and plant catalogues, spraying machinery and spraying-materials catalogues, farm-machinery catalogues, and catalogues of horticultural tools and requisites.

DEMONSTRATION AND DISTRIBUTION.

There has been an unusual demand for advice and assistance from those interested in homesteads. While this department makes no pretense of keeping a stock of plants and seeds on hand for distribution, many of these requests have been filled. The principal plants distributed this past year have been seeds and plants of the papaya, the Kusaie lime, and the rough lemon. The quantity of budded citrus and budded and grafted avocados and mangoes has not been sufficient to supply the sale demands. This department has from time to time filled requests made by other scientific institutions.

NEEDS.

The horticultural department is in need of a rat-proof room for the hardening off of new potted seedling plants, a more effective and permanent soil sterilizer, and a large storage space for tin cans and seed flats.

In closing it is desired to express appreciation of the faithful and efficient services of Valentine S. Holt, acting assistant horticulturist, James H. Cowan, assistant, and of those who have done the detail work of the propagating house and orchards.

REPORT OF THE AGRONOMY DEPARTMENT.

By C. K. McClelland and C. A. Sahr.

Work in this department for the year has been carried on along much the same lines as in previous reports. Taken altogether, the results obtained have not been entirely satisfactory on account of weather conditions and pests. The most complete failure was with corn. Corn was planted in November following several good rains, and grew well from the start. Severe winds during January whipped the plants so badly when they were in tassel that no grain was produced. In a plat in which germination was tardy and the plants less advanced, a better result was obtained.

RICE.

The work with rice is being continued on a small scale in Nuuanu Valley. The lines of work include trials of varieties, aeration of the soil previous to planting, rotation, green manuring, and fertilization. Fertilizers have given no definite results on this land for the past two crops, probably due to the richness of the soil. These plats had not been planted for several years, and a considerable amount of grass and roots was turned under in preparing the land for cultivation. The two following varieties have been grown for the first time during the past year:

Bezembo, a Japanese variety obtained from James Armstrong, of Pearl City, and which is grown quite extensively by him. It was brought from Japan by some of his laborers, and it is preferred by them to the Shinriki variety which Mr. Armstrong has also grown from paddy furnished by this station. In the fall of 1913 it yielded about the same per acre as did Shinriki, but slightly less than did Omachi. It blooms and matures in about 10 days less time than either of the other varieties named.

Long Nyah Yin is a Chinese variety obtained from the Oahu Rice Mill Co. It is a short kernel variety and considerably later than the Japanese varieties. However, the Chinese claim that it will produce two crops. It is also said to be as well or better adapted to salt marsh lands as the No. 19 variety heretofore grown on such lands.

The importation of rice into Hawaii continued at about the same rate, the amount for the fiscal year ending June 30, 1912, being

30,000,000 pounds of rice in the brown; for the year ending June 30, 1913, the amount was 32,000,000 pounds. The shipments from Hawaii to the United States during the calendar year of 1912 were 471,793 pounds, and during 1913, 479,920 pounds. The shipments from the United States to Hawaii during the same years were 52,705 and 319,975 pounds, respectively. The shipments to the United States were mainly of Chinese and Hawaiian rice, while those to Hawaii from the mainland were mainly of Texas-grown Japanese rice. In addition to these shipments, the Quartermaster's Department of the United States Army brought in, during the year ended May 1, 1914, 183,000 pounds, previous to which date their supply was obtained locally. The increase of shipments from the United States in more recent times would seem to indicate that many of the Japanese population have concluded to eat more of the cheaper American rice and less of the imported dearer kinds.

SMALL GRAINS.

Wheat, oats, rye, and barley were planted on limited areas. The wheat rusted badly, and although a few heads matured, the results are such as to hold out little hope of successful wheat raising under local conditions. Rye did excellently at first, and more completely covered the soil, and at an earlier date than did any of the other small grains. While the stand was perfect, when the grain headed out, the appearance was that of a thinly planted plat—the number of heads being about 30 per cent of what they should have been. Oats did better than during the previous year, and averaged, when headed out, about 45 inches in height. As with rye and wheat, the number of heads formed was a very small percentage of what one would term a good crop. Oats at the station make rather a slow growth, and lodge badly before maturing. The wide-leaved varieties are particularly subject to rust.

Barley, though slow in its early growth, headed out better than either oats or rye. Both varieties grown headed at the same time, matured in 150 days, and made a growth of 34 inches. The success of this crop is still uncertain, and further trial is required.

The small grains are attacked by rice birds and sparrows, and with these pests in abundance it is impossible to obtain any accurate data upon seed production.

SORGHUMS.

In an experiment with a sweet sorghum, a nonsaccharine sorghum, and Japanese cane for yields of forage over a long period, the sweet sorghum has yielded, in four cuttings, 47.1 tons per acre, and the nonsaccharine variety 49.8 tons in three cuttings. The Japanese cane cut for the first time yielded 102 tons of forage per acre 453 days after planting. The testing of several varieties of African sorghums for the Office of Forage Plant Investigations at Washington has been attended with some difficulties, such as flood, drought, and severe checking of soil, and the attack of birds. Because of unthriftiness, the first planted sorghums were cut back about September 1, and the ratoon crop allowed to produce seed in the late fall and winter. Because of birds no heads except those covered with wire cloth (held on with spring clothespins) matured, and for that reason very few and often imperfect heads were available for shipment to Washington. A duplicate planting was made on the Wyllie Street plats in October, but these did not reach normal size—heading out early because of cool weather.[1]

SUDAN AND OTHER GRASSES.

Sudan grass planted November 22, 1913, did excellently well. The first cutting, on March 9, 1914, yielded at the rate of 31 tons per acre of green forage; the second cutting, made May 8, was at the rate of 30 tons. The stems of Sudan grass run quite uniformly small and with wide leaves, although occasional plants show a coarseness of stem. The quality of the grass could probably be maintained and improved by roguing out these coarse stemmed plants as fast as they are found, to prevent cross-pollination and consequent deterioration of the seed. With Tunis grass, on the contrary, there is more variability. The majority of the plants have a stem slightly larger than that of Sudan grass, but the leaves are much narrower, and there are many variations with coarse stems and wider leaves. (Pl. III, fig. 2.) Sudan grass is much superior at lower, and Tunis at higher, elevations. At Schofield Barracks the Quartermaster's Department put in about four acres of the Sudan, this being the largest planting as yet made in the Territory. The agronomy department has distributed seed in small amounts to some 40 farmers on the several islands.

New pasture grasses that may prove to be of some value upon lower lands with light rainfall are: Teff grass (*Eragrostis abyssinica*), *Chrysopogon montanus*, and Giant Bermuda. The latter grass has larger stems and leaves and grows more rapidly than does the ordinary manienie. *Chrysopogon montanus* is a perennial grass which has a habit of growth very similar to pili (*Heteropogon contortus*) and it will probably be one of value in the pili country. It will require the same judicious management as does the pili grass. Teff grass is said to be an annual, but has ratooned freely here during its first trial. From a planting made November 15, 1913, the third cutting of mature grass and seed was made May 27, 1914. The stems are small, the leaves fine, and the entire plant appears to be quite palatable. It seeds freely and will doubtless be able to propagate itself under range conditions much as does kakonakona (*Panicum torridum*).

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[1] These long season nonsaccharine varieties of sorghum rarely head out during the warm summer months but seed freely in the cooler fall, winter, and early spring months. No. 309 (S. P. I. No. 25330) when cut Sept. 16, yielded 31 tons per acre of green forage, had no bloom whatever. (See Pl. III, fig. 1.) It and the new varieties now being tested, have been cut twice during the cooler months, the new ratoons heading out again a short time after each cutting. It is possible that dryness during cool weather may influence the bloom somewhat, but it is certain that dryness in hot months exercises no influence. For best yields of seed. however, sorghums should not be cut back in late summer, as was done in the case above mentioned, since with the first rains of the fall, if standing, they grow rapidly and make full crops, but if cut they bloom early with not sufficient growth of plant to fill and mature the seeds.

A number of other grasses were tried out in the grass garden during the year, and although many of them did well, further trial will be necessary in order to determine their value. Mitchell grass (*Astrebla triticoides*), Judd grass (*Leptochloa virgata*), *Paspalum stoloniferum,* molasses grass (*Melinis minutiflora*), *Paspalum virgatum, Phalaris bulbosa,* and Texas blue grass are worthy of mention. The American "Buffalo grass" (*Bulbilis dactyloides*) from Kansas seed started very slowly but is making much better growth as the summer months come on. This is one of the best grasses on the Great Plains area of the United States and should be very valuable on the lower dry lands here.

AUSTRALIAN SALTBUSHES.

Several species of Australian saltbushes (*Atriplex* spp.) lately imported into Hawaii are giving satisfactory results as pasture or cover crops for extremely dry and barren localities. Three varieties tested out are the round-leaved saltbush (*A. nummularia*), slender saltbush (*A. leptocarpa*), and gray saltbush (*A. halimoides*). The first-named species has exceptional qualities in its quick, sturdy growth and prolific seeding habits, while the gray and slender saltbushes, though maintaining vigorous growth, are inclined to seed only during the late summer and fall months. However, all have their merits as sturdy, long-period cover crops.

POTATOES.

But few successful potato crops have been harvested in recent years, due to attack from fungus diseases, of which a late blight seems to be the most serious. The stem and root rot, due to *Sclerotinia rolfsii,* which attacks the stem of the vine in its early growth, is generally overcome by deep and thorough cultivation. It has not been determined whether the blight attacking potatoes in Hawaii and the rotting of tubers are caused by the same organism, but on the mainland where potatoes have been killed by blight (*Phytophthora infestans*) resulting tubers were found to be involved in a soft or wet rot, particularly in instances of moist soil conditions. At the station the loss from rotting of tubers has been particularly large when left undug for several days after the killing of the tops by blight.

Difficulties in obtaining full stands have been corrected by entirely discarding the stem end of tubers for seed purposes. Seed treated with formalin by soaking in a solution of 1 pint 40 per cent formalin to 30 gallons of water produced tubers free from scab in every case except when the soil was freshly limed.

Some spraying experiments were conducted during the year. In each instance the spraying was begun when the plants were 6 or 8 inches high, and six to eight applications were given according to the life period of the vines. With White River potatoes no appreciable difference in yields of tubers resulted from rows sprayed with Bordeaux mixture [1] or copper sulphate and washing soda [2] over unsprayed rows, while with Burbank potatoes yields favored the use of Bordeaux mixture. With Irish Cobbler where an 8 : 8 : 60 [3] solution of lime-sulphur spray was applied in the last two applications the yields favored the lime-sulphur over Bordeaux mixture by an 8 per cent increase, the plants maintaining their thrifty appearance two days longer than those sprayed with Bordeaux mixture and twelve days over check rows. When the potatoes are attacked by the potato tuber moth (*Phthorimæa operculella*) or the flea beetle (*Epitrix parvula*) 1 pound of arsenate of lead added to 50 gallons of Bordeaux mixture is recommended.

BUCKWHEAT.

While buckwheat is best adapted to a cool, moist climate, excellent results were obtained from plantings made in early April. Though the blossoming period was attended by excessively hot, dry weather in May, no loss from the blasting of blooms was perceptible. The two varieties under test (Japanese and Silverhull) yielded 25 and 19½ bushels per acre, respectively, in 56 and 63 days. Buckwheat germinates readily and makes good crops in poor soil if well prepared. The ease and quickness of raising this crop recommends its use in regular rotation, particularly as a poultry feed. For best results buckwheat should be sown in drills one foot apart, requiring about one bushel of seed per acre.

FLAX.

Several trial plantings of flax produced good yields of flaxseed, but rather poor yields of straw. Flax requires a light soil well prepared before planting, germinates in 4 days under good conditions, and matures usually in 90 days. It can be drilled or broadcasted, care being taken to insure an even stand when fiber is wanted for manufacture. The average yield of two plantings upon the station grounds was 17 bushels of flaxseed per acre.

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[1] 6 pounds stone lime, 5 pounds copper sulphate, 50 gallons water.

[2] 5 pounds washing soda, 5 pounds copper sulphate, 50 gallons water.

[3] 8 pounds stone lime, 8 pounds sulphur, 60 gallons water.

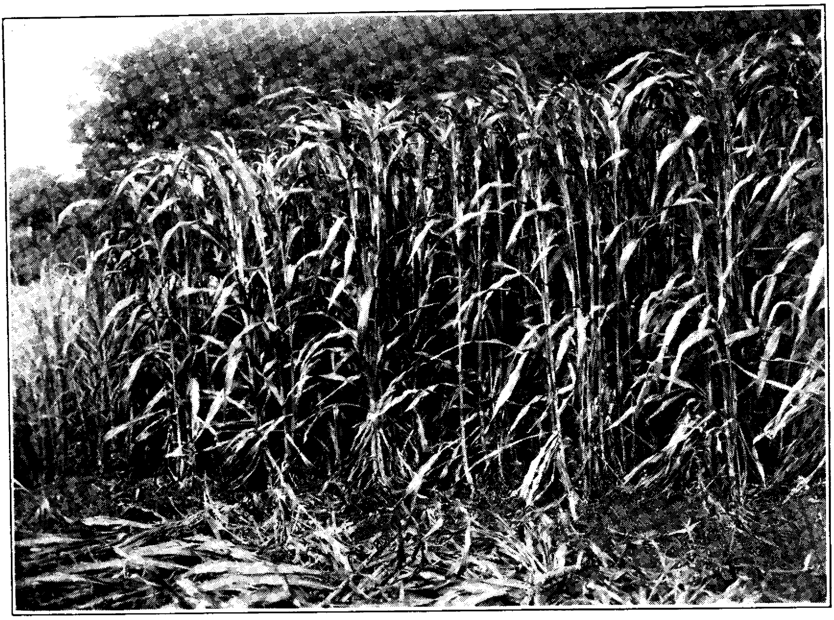

FIG. 1.—AFRICAN SORGHUM, S. P. I. 25330.

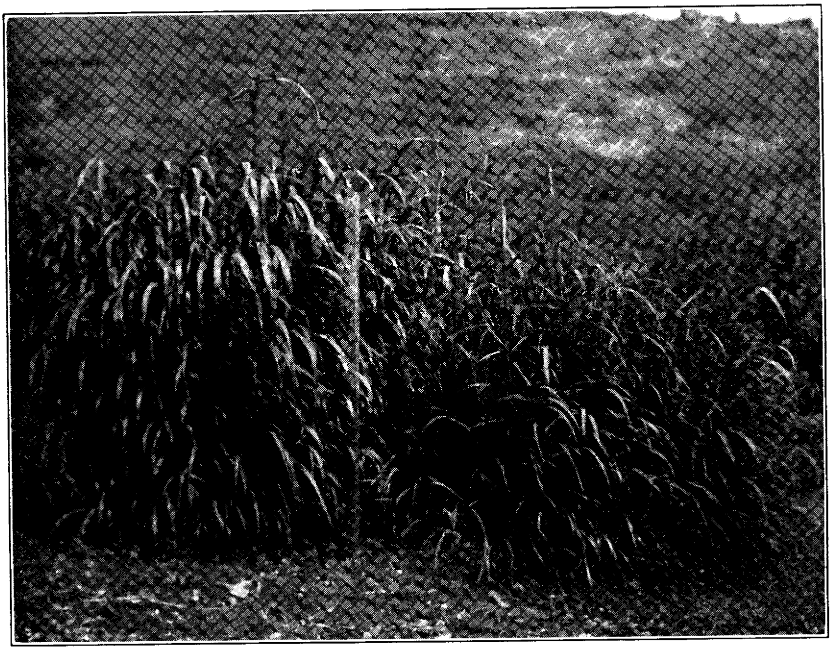

FIG. 2.—SUDAN GRASS ON LEFT, TUNIS GRASS ON RIGHT.

RAPE.

Rape was planted April 5, and grew well at the start. By May 1, when it had gained a height of 10 inches, aphids appeared, and exceedingly hot and dry weather following caused the loss of the entire crop. There seems to be but little doubt that rape will make a good crop when planted at the right season, since it is known that cowpeas, which generally make successful crops, have been killed outright when checked by unseasonable weather conditions together with aphis attack.

LEGUMES.

Of the several legumes introduced during the year German lupine (*Lupinus hartwegii*) gained favor as a green manure crop, yielding at the end of 84 and 96 days, respectively, 9.8 and 18.6 tons green manure and 16.5 bushels of seed per acre. Its habit of growth, while low and spreading at the start, becomes erect and branching as the flower heads appear. Trials with Egyptian clover or berseem (*Trifolium alexandrinum*), Florida beggar weed (*Desmodium tortuosum*), and field burnet (*Sanguisorba minor*) gave fair results, but the field burnet in every trial failed to set blooms and seed. The beggar weed, though known as an annual, has been cut three times, with always a new crop appearing better than the first. Berseem is recommended for higher elevations. The tree lucern (*Cytisus proliferus*); sainfoin (*Onobrychis sativa*), and birdsfoot trefoil (*Lotus corniculatus*) were planted in December, but made little growth until late spring. All but the tree lucern set blooms and pods in May. During early June the sainfoin was attacked by the cottony cushion scale (*Icerya purchasi*), but the plants still held their vigor. In a period of seven months the tree lucern made a growth of 40 inches. The stems are slightly woody, slender, and branching at top.

SUBSTATIONS.

The work at the Kula substation was discontinued at the end of the calendar year 1913. The fall crop of Irish potatoes was a complete failure in spite of spraying. An attempt was made to try out small grains as pasture and green manure crops, the intention being to graze off these crops during the winter months and not to turn them under until time to prepare the land for corn. The crops were turned under, however, after making a good growth in early winter. That these crops will make valuable cover, pasture, and green manure crops at 3,600 feet elevation was fully demonstrated, and it is to be hoped that many in the corn-growing regions will profit by the examples shown them and grow such crops.

At the Waipio substation the agronomy department is interested particularly in a comparison of grain sorghums, Kafir, milo, and feterita. Heretofore all such crops have failed in this location owing to prolonged drought and unfavorable soil conditions. This season the rains have been more favorable, and better results should be obtained.

SEED DISTRIBUTION.

During the year the demand for seed of field and range crops has become greater than ever before in the history of this department. While the demand for cotton seed has come particularly from the Kona district of Hawaii, seeds of velvet beans, jack beans, lupine, cowpeas, soy beans, peanuts, pigeon peas, corn, broom corn, sorghum, millets, and seeds, roots, and cuttings of lately introduced grasses have been chiefly in demand from homesteading districts throughout the islands.

REPORT OF THE ENTOMOLOGIST.

By D. T. Fullaway.

Little entomological work was done at the station during the year, on account of the absence of the entomologist. From July 1 to October 15 he was on detail with the Territorial Board of Agriculture and Forestry. An account of the work performed under its auspices is contained in a recent bulletin published by that organization.[1] From October 15 to February 28 he was on leave of absence engaged in entomological work for the Philippine government. He was away again from June 1 under the auspices of the Territory. The routine work of the office, however, has been adequately attended to and the insect collection maintained and increased by numerous additions, especially an extensive collection of Philippine insects.

Some further work has been done on the insect pests of vegetables, and there follows an account of the insects found in connection with the cultivation of cabbage, turnip, radish, lettuce, etc. Most of these are common and well-known vegetable pests on the mainland and in Europe, which have undoubtedly been introduced into Hawaii in shipments of fresh vegetables. Because of the great losses they have caused in truck farming they have naturally been the subject of many reports and bulletins elsewhere, and in Hawaii they have been dealt with in the reports of Koebele to the Hawaiian minister of the interior, in the annual reports of this station, and at some length in a report by Marsh.[2] Hardly any new or original matter, therefore, appears in this account, but in view of the economic importance of vegetable crops in connection with a growing population, which will provide a constant and ready market for all that can be produced, it is believed that the information here presented in regard to some of the drawbacks and how in part they may be overcome is desirable and will be useful to growers.

The three principal pests of crucifers in Hawaii are the imported cabbage worm (*Pontia rapæ*), the cabbage webworm (*Hellula undalis*), and the diamond-backed cabbage moth (*Plutella maculipennis*). The cabbage aphis (*Aphis brassicæ* and *Myzus persicæ*) are also bad at times. The serpentine leaf miner, cutworms, and other caterpillars of general feeding habits, as well as grasshoppers and thrips, are pests of minor importance.

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[1] Bd. Comrs. Agr. and Forestry Hawaii, Div. Ent., Bul. 3 (1914), p. 148.

[2] Marsh, H. O. [Bien.] Rpt. Bd. Comrs. Agr. and Forestry Hawaii, 1909–10, pp. 152–159.

THE IMPORTED CABBAGE WORM.

The imported cabbage worm is probably as well known as any of the insects which enter into man's domestic economy, and few fail to connect the velvety green caterpillar which feeds so freely on the plants with the large white butterfly which flits restlessly up and down the cabbage or turnip patch. The freedom with which this insect works, in fact, leaves no excuse for ignorance on this point, for often under one's very eyes the butterfly will stop and deposit on a leaf the egg from which the caterpillar later on hatches. It is one of the commonest insects, and it is rare that a cabbage plant can be grown to maturity without being attacked by it. With cabbage grown under field conditions, it becomes an absolute scourge, requiring all the ingenuity, patience, and thoroughness one can possibly develop to cope with it, and as cabbage is the only cruciferous crop cultivated under field conditions in Hawaii, the damage from this insect yearly is very large.

The insect is a well-known European species which became established in eastern Canada, presumably by introduction with vegetables about 1856. Since then it has gradually spread westward and southward in Canada and the United States, reaching Chicago in 1877, the Gulf coast in 1880, and the Pacific slope in 1883. It was first noticed in Hawaii in 1898 and is reported by Koebele[1] to have been introduced with shipments of cabbages from the coast.

The caterpillars are usually found in rather exposed positions on the leaves, which they eat through or gnaw from the edges, giving the outer ones a very ragged appearance. In cabbage which is just heading they often "worm" from leaf to leaf through the head and leave considerable frass behind, which is likely to set up fermentation and spoil the whole plant for any use. Manifestly, the time to deal with these worms is when they are young to half grown, and if the plants can be started in frames under partial cover, so that the butterfly is unable to reach them to deposit its eggs, it is possible to get them well along toward heading with little or no infestation.

The eggs are laid singly on the leaves, usually on the underside, though this is by no means always the case. They are fusiform in shape, placed on end, but with a moderately wide and firm base, are yellow and radiately ribbed, about $\frac{1}{25}$ inch high and readily seen with the naked eye. They hatch at the end of 4 days.

The larva or worm when it hatches from the egg is very small (about $\frac{1}{15}$ inch long). It increases in size rapidly, however, and at the end of 14 days is full grown and ready to pupate. At this time it is an inch or more in length and a velvety green with a yellowish stripe down the middle of the back and a line of yellow spots on either side near the breathing pores.

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[1] Rpt. Min. Int. Hawaii, 1898, p. 87.

The worm often leaves the plant to pupate in the shelter of some convenient object, but the pupa is also sometimes found fastened by a silken girdle to a leaf of the plant. It is about $\frac{3}{4}$ inch long, angular and ridged, in places somewhat spiny, green to gray, flecked with black; the frontal projection is rather long and sharp with two stout spines behind; at the tip are many closely crowded recurved hairs or spines. The pupal stage is from 8 to 12 days.

The adult butterfly has a wing expanse of 2 inches, is yellowish white, marked with black near the tips of the forewings and a black spot on the disk (two in the female); also a similar spot on the costal margin of the hind wing. It has a slow and lumbering flight, but is extremely active, especially on bright days. One female was observed to lay more than 20 eggs in less than an hour without exhausting herself.

Arsenic sprays are recommended to reduce this pest (arsenate of lead or Paris green and lime). Boiling water is also considered good. The spray must be applied to the underside of the leaves as well as the upper; the spraying outfit therefore should be provided with an extension rod.

The tachinid fly, *Frontina archippivora*, is very commonly bred from these worms and it undoubtedly does much to check their multiplication. *Chalcis obscurata* has also been bred from the pupa, and a bacterial disease is quite common among the worms.

THE IMPORTED CABBAGE WEBWORM.

The imported cabbage webworm, although much more obscure in its operations than the common cabbage worm, is nearly if not fully as destructive. It is equally prolific and just as injurious to cabbage and related crops. In fact, it is more to be dreaded than the other species on account of its peculiar habit of attacking particularly the bud, and because of its ability to escape the action of insecticides in the protection of its web. The pest is found in the Mediterranean region and generally throughout the tropical portions of the Old World. It was apparently of early introduction into Hawaii, as examples were taken by Perkins (1892–1895). It was not generally recognized as a pest in the States until 1897.

The eggs are usually laid about the bud, in the axils of the terminal leaves, oftentimes also on the upper surface of the leaves in the hollows formed by the leaf veins. They are extremely small (about $\frac{1}{50}$ inch), oval, not particularly flat, and are yellowish white flecked with reddish spots and microscopically sculptured. They hatch in from 3 to 5 days.

After hatching from the egg the young larva begins to feed on the leaves, especially the young tender leaves of the bud, and usually spins a web about itself between two leaf surfaces. Often it mines into the stalk or midrib of the leaf. The result of its work quite frequently is the complete destruction of seedling plants. Larger plants are either stunted or deformed, so that they can not make a normal growth. The worm is full grown in about 18 days, and at this stage is about ½ inch long, fairly stout and hairy, with head black and body yellowish brown marked with a thin dark-brown stripe down the center of the back and two similar stripes on the sides, the inner of which is wider than the outer.

The worm pupates in the ground in a rather loose cocoon made of particles of soil webbed together with finely spun silk. The pupa is a quite ordinary kind about ⅓ inch long, shining light brown with dark stripe on back, and a bunch of four fairly long recurved hairs at the tip. The pupal stage lasts from 10 to 15 days.

The adult moth has a wing expanse of ¾ inch, is generally gray, the forewings with darker areas about two wavy white lines which cross the disk at about one-third and two-thirds its length. They fly readily, but are more or less obscure in their habits, and are not often seen in the cabbage fields.

H. O. Marsh experimented on the control of this pest with different insecticidal mixtures, but found nothing that could be depended upon, and recommended screening the seed beds and clean culture as the only means of lessening its depredations.[1] He recommends cotton mosquito netting, but the writer has found wire netting more suitable, and the plants should be 5 to 6 inches high and have a vigorous growth before being set out. The braconid, *Chelonus blackburni,* is a very common parasite of this species.

THE DIAMOND-BACKED CABBAGE MOTH.

The diamond-backed cabbage moth takes its popular name from the peculiar diamond-like pattern of the coloration of the moth; the damage to the crop (cabbage, turnip, etc.), is done entirely by the worm, which is now almost cosmopolitan. It probably originated on the Continent, where it first came to notice as a vegetable pest. In the early fifties it was discovered in the United States; later it was found in Australia, New Zealand, South America, and in Africa, at the Cape. According to Koebele, it was an early introduction into Hawaii.

The damage to the plants caused by this pest results from the destruction of the leaves, which the worms, when present in force, quickly riddle with holes. As the species is extremely prolific, the plants are soon shattered, unless in some way protected.

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[1] Chittenden, F. H., and Marsh, H. D. U. S. Dept. Agr., Bur. Ent. Bul. 109, pt. 3 (1912).

The eggs are deposited singly in large numbers on the leaves, usually in the hollow alongside a leaf-vein. They are extremely small ($\frac{1}{40}$ inch), flat, oval, lemon yellow, with iridescent, roughened surface, and hatch in 4 days.

The larva, when hatched from the egg, is very small, but increases in size gradually with age. At the end of 10 days it is full grown and ready to spin its web and pupate. At this time it is a remarkably active slender green worm, nearly $\frac{1}{3}$ inch long, somewhat constricted along the body, which bears microscopic dark spots and hairs. If suddenly disturbed it is most likely to wriggle away with some very lively contortions and drop from the leaf, suspending itself by a silken thread. It is at this period of its cycle that the insect is destructive and also most susceptible to attack with poisons, washes, etc., but its concealed position on the unexposed portions of the foliage must be taken into consideration.

The pupa, as already intimated, is partially concealed and protected by a rather unique, loosely woven, wide-meshed web, attached on all sides to the surface of the leaf. It is a little less than $\frac{1}{4}$ inch long, slender, greenish yellow to pale brown, with a few small tubercles on the head and a bunch of spiny hairs at the tip. Within it the moth develops in from 6 to 8 days and emerges by bursting through the anterior end of the case and its web.

The moth is about $\frac{1}{3}$ inch long with the wings closed and measures $\frac{1}{2}$ inch across when these are spread out. It is generally an ashy gray. The forewings, however, are flecked with black on the disc and apex and have a wide black streak extending from the base through the middle for about half their length. Between this area of black and the hind margin the wing is creamy white, the line of separation usually somewhat wavy. The hind wings are a glossy leaden gray, the antennæ and underside of the body almost white.

Sprays are recommended to reduce the damage of this destructive worm in cabbage and turnip fields, and the remedies commonly used for the other cabbage worms (arsenic, kerosene emulsion, and hot water) are effective for this pest as well. The multiplication of the insect is also greatly checked by the hymenopterous parasites, *Limnerium blackburni*.

These three species, which have been especially mentioned, are all, with regard to their food plants, confined entirely to crucifers, although my observation from the beginning has been that the injurious effects in the case of each species are more noticeable in some crops than in others. Thus the cabbage worm (white cabbage butterfly) does more damage to cabbage than to other crops, although turnips and cauliflower are also attacked. The worm of the diamond-backed moth is most injurious to thin-leaved plants and seedlings; on the tough rubbery leaves of cabbage it has hardly any effect. The webworm does greater damage to root crops—radishes and turnips—on account of its habit of eating out the bud. It also destroys the foliage of thin-leaved plants.

OTHER PESTS OF CRUCIFERÆ.

The best known aphid in connection with crucifers is the common cabbage louse, *Aphis brassicæ*, but in Hawaii this species is much less numerous than another, *Myzus persicæ*, which on the mainland and in Europe is found principally in connection with the peach. The two species are entirely dissimilar, the latter being a naked green louse, while the former is always covered with a whitish mealy coat. The injury inflicted by aphids results from the withdrawal of the cell sap of plants, causing the rapid withering of the leaves, which may be a mere temporary disturbance or fatal, depending on the extent of the infestation. Both species here are effectively controlled by a hymenopterous parasite (*Diæretus rapæ*) and the dry tumid bodies of parasitized individuals are a common sight on the outer leaves of any crucifer. Aphids, therefore, would be considered a negligible factor in the cultivation of cabbage and related crops were it not for the fact that peculiar weather conditions in Hawaii sometimes favor the rapid multiplication of these pests and occasionally seed-bed plants become badly infested with *Myzus persicæ* so that the plants are greatly retarded or killed outright. These infestations may be promptly remedied by spraying the plants with whale-oil soap (1 pound to 5 gallons of water), blackleaf 40 (1 fluid ounce with 3 ounces of whale-oil soap and 4 gallons of water), or miscible oils (directions for the application of which usually accompany the containers).

The serpentine leaf miner is extremely conspicuous in vegetable gardens where thin-leafed crucifers, such as turnips, daikon, shirona, etc., are growing, but is of no great importance as a crop pest on account of the trivial nature of its injuries and its heavy parasitization. It has recently been studied in the United States by the entomologists of the Department of Agriculture, who found that the same insect previously known under several different names attacks a wide variety of plants. It does the same here, and has been found in geranium, nasturtium, and beets in addition to many cruciferous and leguminous crop plants. The insect is a common European pest which has spread eastward into Egypt and westward upon the American Continent. The damage it causes, as already indicated, is slight and comes from the injury to the foliage caused by the mines of the larvæ or maggots. The eggs are laid deep in the mesophyll of the leaf, are white, oval, and almost microscopic in size ($\frac{1}{100}$ inch). They hatch in 4 days. The larva begins its mine from the position of the egg and its progress is indicated by a bleached wandering track which enlarges with the growth of the maggot and may end in a pocket. The larva is a slender, shining, yellowish maggot about one-eighth inch long when full grown, with spiracular protuberances and black oral appendages which are almost constantly in motion, rasping away the mesophyl. It continues feeding and advancing in the leaf until it is ready to pupate, usually for 9 or 10 days; then it leaves the leaf end and enters the soil. The pupa is inclosed in an oblong, oval puparium about one-twelfth inch long, distinctly segmented, brown, and with prominent spiracular openings in front and behind. The insect remains in the pupal stage for 6 days, at the end of which the perfect insect emerges. This is a small black and yellow two-winged fly so commonly seen hovering about the cabbage patch. The cycle of the fly in Hawaii according to the above data, which were obtained in April, requires from 20 to 25 days. There would probably be some acceleration of the development in the summer and a slight retardation in the winter months.

Three hymenopterous parasites have been bred from the species belonging to the genera Derostenus, Diaulinus, and Chrysocharis. These are usually active enough to keep the pest well checked and no remedial measures are suggested or considered necessary.

Several species of thrips are also commonly found on crucifers but can not be considered of much importance from the growers' standpoint. The commonest is the onion thrips (*Thrips tabaci*), a pale species. Less common is a dark species of Chirothrips.

Cutworms are also occasionally found and are the common garden species which have been repeatedly reported as attacking succulent plants indiscriminately (*Agrotis ypsilon*, *A. crinigera*, and *Caradrina exigua*). A few other leaf-feeding caterpillars have also at times been encountered. *Hymeria fascialis*, *Plusia chalcites*, and the long-horned grasshopper (*Atractomorpha crenaticeps*). All these are adequately controlled by parasites and are not particularly injurious, but if so at all, their prevalence is in the nature of an outbreak which can scarcely be foreseen, is easily checked by arsenic sprays, and at all events is not likely to be of long duration. The melon fly (*Dacus cucurbitæ*) has often been reported infesting the heart of cabbage, but the infestation is not at all common and is considered to be due to abnormal conditions in the plant, and of a secondary nature.

One of the principal sources of trouble in growing cruciferous crops is the absence of clean cultivation. Specific measures of control have been advised in the case of each of the pests above discussed, but these measures relate to infestations which already prevail. Unfortunately, also, they entail considerable labor and expense and are often partly or entirely ineffective. In many cases, moreover, the conditions would be very different if clean cultivation had been constantly practiced. This applies particularly to the control of the more insidious pests and to districts where cruciferous crops are raised continuously from year to year. In such places the production of cruciferous crops with profit after a time becomes almost an impossibility owing to the cumulative factor in the natural increase of the pest concerned. It is therefore desirable that when the crops are taken off the stumps be pulled and these together with discarded leaves and all other trash in the fields be disposed of so that the insects in them are unable to breed out. This might be accomplished by deep plowing, though the results would undoubtedly be better if the trash were burned or buried several feet below the surface of the ground. This measure is almost essential in dealing with hardy insects in a country where breeding goes on throughout the entire year, and would take the place and bring about the beneficial results in the way of insect destruction attending the long seasons of low temperature in more northern latitudes.

REPORT OF THE SUPERINTENDENT OF THE RUBBER SUBSTATION.

By W. A. Anderson.

The most important developments at the rubber substation were in connection with observations on the latex-bearing qualities of individual trees, the possibility of propagating for these properties, and the suitability of roselle as an intercrop for rubber.

PLANTING CUTTINGS.

The wide variation in the yields of individuals among Ceara (*Manihot glaziovii*) rubber trees, suggests the possibility of developing a plantation by propagating from exceptionally good yielders with a view to eliminating this wide variation, and obtaining a stand on which all the trees will be large yielders. Seedlings can not be depended upon to come true, and, consequently, in 1912, an experiment was planned to determine the feasibility of transmitting high yielding properties through cuttings.

In February, 1912, 200 cuttings of various size were taken from trees that were considered good yielders, and planted on land belonging to The Hawaiian American Rubber Co., in Nahiku. During 1912 broom corn was planted among these trees, and in 1913, roselle, so that they have been fairly well cultivated during the two years. In January, 1914, when the trees were 1 year and 11 months old, they were tapped with a single cut. The new growth on these trees, 1 foot above the original cutting, averaged 10.8 inches in circumference. They yielded 16 ounces washed rubber from one tapping, of one cut per tree. This is equal, in both yield per tree and returns for labor, to the average reported from 6-year old trees unselected, tapped in 1912. The yield from the different trees was more uniform than on the plantations as a whole, and the results indicate that this method of propagation can be successfully employed to transmit desirable latex-yielding properties.

It was also observed, in tapping experiments on 7-year old trees in the fall of 1913, that the best trees yielded as high as 2 ounces wet rubber at one tapping equivalent to about 1.36 ounces dry rubber. By the method employed in obtaining this yield, one man averaged 200 trees, tapping and collecting, per day's work. The number of these high yielding trees is small, averaging probably not more than one or two per acre over all the plantations. If all the trees yielded in this manner, rubber could be collected at the rate of 17 pounds dry rubber per man a day. At $1 per day, the average wage for tapping, the rubber would cost about 6 cents per pound for tapping alone. Factory expense, packing and shipping, freights, insurance, and commissions should not exceed 15 cents per pound, and in large quantities could be made much less than this. Other overhead charges would depend on the amount of rubber produced, and can be estimated only on the basis of the number of trees tapped and the yield per tree per year. However, at these figures, there would seem to be a fair margin of profit, even at the present price of rubber.

This high yield of the best trees, coupled with the indication that the high-yielding properties can be transmitted through cuttings, suggests a method by which Hawaiian rubber can be produced at a profit even with low prices for the product. By discarding all unprofitable trees, and planting cuttings from these few best trees, plantations can be developed from which rubber can be obtained at a low tapping cost. This experiment at its present stage, indicates only that the trees obtained from cuttings in this way will give more uniform and larger yields than can be obtained from the ordinary methods of planting with seedlings. Whether trees raised from cuttings taken from trees yielding 2 ounces per tapping, will likewise yield 2 ounces per tapping, can be determined only by keeping a record of the trees from which the individual cuttings were made, and comparing the yield from the resulting trees when they shall have reached the age of the parents at the time the cuttings were taken. As the trees from which 2 ounces per tapping was obtained were seven years old, it would take seven years to determine this point definitely. However, since the yield from these 2-year old cuttings equalled the average yield from ordinary 6-year old trees, it would seem reasonable to assume that it was approximately as large as that of the present trees at two years of age. It will be interesting at least to watch these young trees and to note their performance at maturity.

ROSELLE.

Roselle (*Hibiscus sabdariffa*) was planted on a commercial scale between the rubber trees on two of the plantations during 1913. Results indicated that, with a market for the fresh fruit at 3 to 4 cents a pound, this would be a profitable intercrop. At present, however, there is practically no market for the fresh fruit while a limited market does exist for the dried fruit at 30 to 40 cents per pound, which is equivalent to 2½ to 3⅓ cents per pound for the fresh fruit less the cost of drying.

Even at this price, however, the results of last year's experiment were so promising that five farmers besides two of the rubber plantations are planting this year, with a total area of about 220 acres.

The rubber trees among which the roselle was planted were spaced 10 by 20 feet. The roselle was accordingly planted 5 by 5 feet as the most convenient spacing to utilize the soil in conjunction with the trees. This is rather close planting where the bushes grow as large as in the Nahiku district. In the early plantings on the lower elevations, the plants grew to a height of 8 to 10 feet, bearing the fruit rather too high for convenient picking. These plants yielded, however, at the rate of 10 pounds of fruit per plant, or roughly, 15,000 pounds per acre among the rubber trees. With the same yield per plant, and the rubber trees replaced by roselle plants, we should have had over 17,000 pounds per acre, which is a larger yield than has been elsewhere reported.

During the same year a planting of 25 acres was made in the Kona district of Hawaii, under the supervision of Mr. R. V. Woods, of the Kona Kanning Ko., who reported the results as indicating that, while planted as a catch crop among other things it might prove profitable, it was not profitable as a crop by itself. The failure in Kona was no doubt partially due to the unusually dry season during the period of growth, while the copious rainfall in Nahiku may be partially responsible for the highly satisfactory yield in this district. During the eight months from the time the first seed was planted to the time of harvesting, the precipitation amounted to 109.17 inches. The partial protection from the trade winds afforded by the rubber trees among which they were planted may also have helped to increase the yield. Whatever the causes, the results would indicate that the Nahiku district is well suited to the growing of this fruit among rubber trees.

Considerable difficulty was experienced in drying the fruit. It was at first thought that the drying could be done at ordinary temperature in a drying house built according to the plan given for a tobacco drying house.[1] Harvesting began in November, and during this month 26 inches of rain fell. It was found the fruit would not dry without artificial heat. Consequently, the drying house was equipped with steam heat. While the building was poorly adapted to this method it was found that, at a temperature of 120 to 140° the fruit would dry bone dry in 24 to 48 hours. The proportion of fresh fruit to dried was roughly the same as previously reported from the experiment station grounds in Honolulu.[2]

Picking is the most expensive operation in connection with the handling of the crop. At first the fruit was picked and carried complete to the drying house, where it was seeded into the drying trays. It was found cheaper, however, to remove the seed pod in the field at the time of picking. This avoids one handling of the entire weight of the fruit, and saves about one-third in the weight that must be transported to the drying house. At the same time, it avoids another handling of the seed pods, which must be removed from the drying house after seeding by the first method, and leaves the green seeds and pods on the field for whatever fertilizing value they may have. With the price of labor averaging $1 per day, it cost 2 cents per pound of seeded fruit to harvest the crop in this way. The saving in handling and transportation was the chief advantage of the second method.

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[1] Hawaii Sta. Bul. 15.

[2] Hawaii Sta. Rpt. 1909, p. 55.

Considerable loss was experienced from cutworms, both in the nurseries and after transplanting. This has been largely avoided this year by protecting the nurseries with ditches, planting as much as possible between the cutworm seasons, and allowing the plants to remain longer in the nurseries before transplanting. Not only the planting in nurseries, but the transplanting should be done between the cutworm seasons as far as possible. If not planted too thickly in the nurseries, the seedlings can be allowed to reach a height of 1½ to 2 feet before transplanting, without serious injury. This has a tendency, however, to make them branch high, and a better size for transplanting is 6 inches to 1 foot. With the seedlings ready in the nurseries, a few can be transplanted and watched a few days for evidences of cutworms. When it is found that the cutworms do not attack these, the transplanting can be done with comparative safety. Losses from this source this year have been negligible.

The work on this crop has shown:

(1) That large yields can be obtained in this locality when planted between rubber trees;

(2) That some means must be provided for drying artificially;

(3) That unless precautions are taken cutworms will cause serious losses, but that this loss can be largely avoided; and

(4) That if the work is all done by hand with tools now available, the crop can be most economically handled by picking and seeding at one operation in the field.

The value of the crop planted this year by five farmers and two rubber companies is conservatively valued at $52,800.

There is some indication that certain of the plants, by proper handling and judicious pruning, can be made to grow and bear a second year. This would seem to be a proper subject for further investigations.

EFFECT OF FERTILIZERS ON THE YIELD OF RUBBER.

The object of this experiment was to determine the advantage, if any, in the use of the ordinary fertilizers to increase the yield of rubber during a tapping season. A block of 1,000 trees was divided into 10 plats, numbered 1 to 10. The odd sections were left unfertilized for check, and the even sections fertilized with equal amounts of phosphoric acid in the form of superphosphate, potash in the form of potassium sulphate, and nitrogen in the forms of sodium nitrate and ammonium sulphate. The trees were measured at the beginning and at the end of the experiment. The sodium nitrate was divided into four applications, but rainy weather destroyed the results of the tapping after the last application, so that the results are tabulated for only three series of tappings with three-fourths of the nitrate.

Ten tappings were made during September, October, and November, and five during February. Sodium nitrate was applied just before each of the tappings. In the three series of tappings, results per tree were as follows:

Effect of fertilizers on yield of rubber.

Plat No.	Fertilizer.	Yield.
		Ounces.
1	No fertilizer	1.54
2	Superphosphate, 375 pounds, and potassium sulphate, 125 pounds	1.57
3	No fertilizer	1.1
4	Superphosphate, 375 pounds; potassium sulphate, 125 pounds; and ammonium sulphate, 375 pounds	1.4
5	No fertilizer	1.32
6	Superphosphate 375 pounds, potassium sulphate 125 pounds, and sodium nitrate 375 pounds	1.4
7	No fertilizer	1.43
8	Ammonium sulphate 375 pounds	1.55
9	No fertilizer	1.44
10	Sodium nitrate 375 pounds	1.48

Comparing the yield per tree from each of the fertilized plats with the average from the two unfertilized plats on either side, plat 2 exceeded plats 1 and 3 by 19 per cent, plat 4 exceeded 3 and 5 by 15 per cent, plat 6 exceeded plats 5 and 7 by 5 per cent, plat 8 exceeded plats 7 and 9 by 8½ per cent, and plat 10 exceeded plat 9 by 3 per cent. Had all the scrap been collected, the nitrate fertilized plats would have made a better comparative showing. The trees on these two plats retained more rubber after each tapping that had coagulated on the trees. This was more noticeable in the case of plat 10, fertilized with nitrate alone.

Following are the girths of the trees in inches, at the beginning and at the end of the experiment:

Effect of fertilizers on circumference growth of rubber trees.

Plat No.	Fertilizer.	At beginning of experiment.	At end of experiment.
		Inches.	*Inches.*
1	No fertilizer	16	17.9
2	Superphosphate 375 pounds, potassium sulphate 125 pounds	15.97	18.5
3	No fertilizer	15.75	19.6
4	Superphosphate 375 pounds, potassium sulphate 125 pounds, and ammonium sulphate 375 pounds	17.23	19.2
5	No fertilizer	16.9	19
6	Superphosphate 375 pounds, potassium sulphate 125 pounds, and sodium nitrate 375 pounds	16.34	18.4
7	No fertilizer	15.55	18.4
8	Ammonium sulphate 375 pounds	14.78	16.5
9	No fertilizer	16.5	18.1
10	Sodium nitrate 375 pounds	15.2	17.7

With the exception of plat 3, the largest increase in girth is in the section fertilized with superphosphate and potassium sulphate. Why it should be greater in this case than in that of the trees fertilized with these fertilizers plus ammonium sulphate or sodium nitrate is hard to say, but the same was noted in measurements of trees on which an experiment was made in 1909 and 1910.

In general, the results show an increased yield resulting from the use of fertilizers. The increase varies from 3 per cent, in the case of nitrate alone, to 19 per cent, in the case of superphosphate and potassium sulphate.

Superphosphate and potassium sulphate, in combination with ammonium sulphate, show a greater increase than the same two in combination with sodium nitrate. Superphosphate, potassium sulphate, and sodium nitrate show an increase of 19 ounces between the first and third tappings. The largest yield per tree was obtained from superphosphate and potassium sulphate. The next largest from ammonium sulphate alone, though this was only 0.07 ounce greater than that obtained from three-fourths as much sodium nitrate. The difference in cost of material and application would perhaps be the determining factor in deciding between these two. The largest difference between the yield of fertilized and adjacent unfertilized trees was also obtained in the case of potassium sulphate and superphosphate.

REPORT OF THE SUPERINTENDENT OF THE HAWAII SUBSTATIONS.

By F. A. Clowes.

HILO SUBSTATION.

BANANAS.

During the year the experimental plat for studying the influence of planting bananas at various distances apart, as described in the annual report of this station for 1912, was replanted. In replanting, a plat was added in which the bananas were 6 by 6 feet apart. This plat will be harvested in the latter part of 1914.

TARO.

A quarter of an acre was planted in taro in February to determine the relative value of three classes of seed, or hule, namely the parent or makua, the oha or seed from large tubers, and the piu, or small tubers. This area had been planted in 1911, and harvested in 1912. It is intended to replant it at least three times before attempting to draw conclusions. In the 1911 experiment, just one variety, the Kuoho was used. In the 1913 experiment the following varieties were used: Kuoho, Eleele, Lehua, Makaua, Papa pulo, and Nana (Ulaipio). The experiment will be a test of some of the standard varieties, as well as a "seed"-selection test. The crop will be harvested in the latter part of 1914.

SCHOOL GARDENS.

The classes in agriculture of the Hilo Union School were given the use of the interspaces between the freshly-planted bananas for six months. Gardening was done on this land under the direction of E. G. Allen, of the Hilo High School. A study of the work done by these classes suggests ideas which promise to be of value in developing the possibilities of teaching agriculture. A half acre of the substation has been set aside for the use of the classes next year and an effort will be made to develop farther the possibilities of teaching agriculture through school gardens.

GLENWOOD SUBSTATION.

In Olaa comparatively few days go by without rainfall. In upper Olaa it is not uncommon for a month to pass with but a half dozen glimpses of the sun. From April 1 till June 30, 1914, eight acres intended for spring planting at the substation lay fallow waiting for suitable weather to render it dry enough to harrow. This is not at all an uncommon occurrence in Olaa as elsewhere on the windward sides of the larger islands, at elevations above fifteen hundred feet. Nevertheless, periods of several weeks will elapse when sunny skies and slight precipitation prevail. There is, however, no definite dry or wet season and all empirical rules regarding the weather probabilities are very uncertain. The conditions are so different from European and American conditions, that there is little recorded experience available to aid in developing a system of agriculture suited to this region.

Farmers in Olaa are adopting a system of agriculture apparently suited to the climate. The popularity of soiling crops such as honohono (*Commelina nudiflora*) and Para grass can be accounted for by the fact that they are perennial and require little cultivation other than top-dressing with manure. Their use is becoming general where any attempt at all is made to supplement the natural pastures by green crops. It is probable that an extension of the present crude system of live-stock farming with honohono and Para grass as the main crops, could be made very profitable. In the summer months there is much more growth than during the winter. Honohono lodges badly and Para grass becomes woody if left in the field after a certain stage of development. To prevent loss of the surplus in summer, some means of storing is needed. The silo offers one means of solving this difficulty. A hay-drying kiln, either under cooperative or individual ownership, would offer an additional means of storing feed, and would also make Para grass hay a possibility. Since practically all the hay used in the Territory is imported it would seem that a ready market is at hand for a great deal of hay which could thus be a by-product of the live-stock farms of this region. The care of manure is a problem that requires study. There is little available litter to be used as an absorbent. It is consequently difficult both to keep cattle clean in the stable and to absorb the liquid manure to make it convenient to handle. Some dairymen are saving the liquid which is voided while the stock are in the stable by running it into barrels and then carrying it out in buckets. While this means is effective it needs modification in the interests of economy of labor. The matter of economical methods of handling this valuable by-product of the live-stock industry merits attention, since the difference between profit and loss in manufacturing and agricultural industries largely depends upon the advantageous utilization of the by-products.

An island-bred mare of good medium heavy type was purchased in July. The prime object in buying her was to secure a work animal. She has been bred to a large standard-bred stallion.

CATTLE.

During the year the station herd of cattle was increased by the birth of two bull and two heifer calves, all pure-bred Guernseys, eligible to registry. The herd bull, Raymond of Alta Vista, has stood for service throughout the year. All the farmers within reach have taken advantage of this opportunity. A census of the calves in the neighborhood shows that there are 15 grade heifers sired by the substation bull, distributed among 9 different owners.

POULTRY.

In January a small flock of Rhode Island Red chickens was purchased. White Leghorn eggs were also purchased and hatched in an incubator and the chickens reared indoors in deep litter brooders. It is intended to increase the flock of poultry this year, to study problems connected therewith, and by trap-nesting to develop a high egg laying strain in order to supply farmers with more productive laying stock. A small flock of White Muscovy and another flock of Indian Runner ducks has also been purchased.

CREAMERY.

It had been hoped that the cooperation of all the dairymen within reach could be secured for the Glenwood Creamery Co., which was organized with the assistance of the substation. This cooperation was not secured. Sufficient interest had not been developed among the patrons in delivering sweet cream and the grades established proved to be too low. During the warm months of summer the butter lacked keeping quality and the best prices were not secured. It was proved, however, that sweet cream could be delivered without the use of ice by attention to cleanliness and promptly cooling cream to air temperatures. The output of the creamery was only half of what has been hoped for. This made the cost of manufacture double what was expected. It became apparent, therefore, that it was not advisable to continue operating the creamery as a cooperative enterprise. The company therefore resolved itself into a cooperative marketing association in December. To date it has been doing satisfactory work as a cooperative marketing and buying association, and the field of its operations is extending. Ultimately, it may establish a creamery when circumstances justify it. The substation has rendered it special assistance, because it is a pioneer organization of its kind so far as Hawaii is concerned. It is now so well established that the assistance of the substation is no longer required.

The substation has bought cream from a few neighboring farmers and is making butter to study problems which arise in connection therewith. The butter made is marketed through the creamery company.

CORN AND SORGHUM.

Three acres of corn of the native white variety from Waimea were grown for the silo. A representative row in this field was weighed and produced at the rate of 8.5 tons per acre. Two acres of Early Orange sorghum were grown for the silo. A representative plat of the field was weighed and produced at the rate of 12.5 tons per acre. Part of the sorghum field was allowed to ratoon, and was used for green fodder as required.

GRASSES.

Para grass maintains its lead as the most promising grass for pasture or soiling purposes.

Giant water grass, Natal grass, Italian rye grass, orchard grass, and redtop have all done well and would probably be valuable as pasture grasses.

The area of honohono for soiling purposes has been increased as rapidly as the supply of stable manure permitted. There is now about a half acre which is being cut for stable feeding, daily, and top-dressed with manure after each cutting. Records of the yield are being kept in order to make comparisons with Para and other grasses.

LEGUMES.

Soy beans were sown broadcast on the corn stubble in November. A very poor stand was secured, which was plowed under in January and the ground planted to wheat and kidney beans. These produced a light growth, which was plowed under in March, as green manure. No satisfactory results were secured from any legumes.

EXTENSION WORK.

During the year assistance was rendered in the organization of two associations of cane planters. One was the East Hawaii Cane Planters' Association, an organization of English speaking cane planters, and those interested in sugar cane. The purpose of the organization was to assist in matters of interest mutual to the members of the association. It is intended to work along the lines adopted by farmers' clubs elsewhere.

A federation of associations similar to the above was also formed. This federation adopted the name of "Hilo-Puna Cane Planters' Union." It aims to federate all associations of cane planters, regardless of language and locality. The unit organization paid into the union assessments at the rate of 30 cents per year for each acre cultivated or controlled by the individual members of the associations. The fund thus raised is being used to secure expert assistance from legal and chemical advisers in connection with difficulties that arise in regard to the marketing of sugar cane. The charter members of the union are the Hakalau Sugar Planters' Association, the Wainaku Sugar Planters' Association, the Honomu Sugar Planters' Association, and the East Hawaii Cane Planters' Association. The union is accomplishing much good by overcoming causes of friction between cane planters and mill managers.

During the year six talks were given to the classes in agriculture at the Hilo Boarding School and the Hilo High School.

SILO.

In September a concrete pit silo was built, 12 feet in diameter, and 12½ feet in depth. The bottom is 4 feet below the level of the stable and the top level with the top of the bank at the rear of the stable. This was filled twice, in October and February. A 7-inch hand-power feed cutter, equipped with a pulley and driven by a 1½ horsepower gasoline engine, was used to cut up the fodder. The feed cutter was placed on timbers across the top of the silo so that the cut fodder fell from the machine directly into the silo.

In October the silo was filled with corn, sorghum, and Para grass; in February it was filled with sugar cane, sorghum, and Para grass. Special interest is attached to the ensiling of sugar cane and Para grass, as the use of these two crops in the silo is comparatively new. Sugar cane made excellent silage, very sweet, little more acid than corn silage, with very agreeable odor, and was readily eaten by the stock. Para grass, mixed with a little honohono, also made silage which the stock ate readily, though of a less agreeable odor than other standard silage crops. Both of these crops are big yielders and are promising for cattle feed.

In June a 20-foot redwood silo was placed on top of the concrete silo already in use. This made a silo 32½ feet deep by 12 feet in diameter. This was filled with cane tops in June in cooperation with the Olaa Sugar Co.

THE COMPOSITION OF HAWAIIAN FRUITS AND NUTS.

By ALICE R. THOMPSON, *Assistant Chemist.*

INTRODUCTION.

The analyses on which this report is based were made to gain information upon the chemical composition of the common fruits and nuts which occur in the Territory. The station receives frequent requests for information regarding the composition of ripe fruits of various kinds and regarding the changes in composition which take place during ripening. Almost every fruit consumer has preconceived notions or desires to know more about the nature of his favorite fruits, their nutritive value and possible physiological effects.

Many of the fruits studied by the station have been previously analyzed, but few of these analyses are based on Hawaiian specimens. Moreover, the analyses were made in various parts of the world, in many cases, from fruits which had been shipped long distances in cold storage. The results thus obtained are not strictly comparable, one with another, for the reason that they were obtained by various chemists and by various methods. The variations observed in the published analyses of a given fruit are due to differences in climatic and soil conditions, stage of ripeness, degree of freshness of the fruit, method of analysis, and perhaps to other factors. The analyses reported were all made by the writer according to one uniform method. All the fruits and nuts came from one locality. Only normal, fully ripe fruits were used. They were picked in the morning and analyzed on the same day. The results, therefore, reliably represent the relative percentages of various constituents in an unusually large list of fruits and nuts from one locality.

In the case of the mango, avocado, papaya, and citrus fruits, several varieties of each were analyzed. Interesting variations in the composition of varieties of the same species were found.

The chemical changes which take place during the ripening of fruits are of great interest from a scientific as well as from a practical standpoint. The station had previously studied the ripening of pineapples. A similar study was made of bananas and papayas. Interesting data on the ripening process in these two fruits are herein presented.

METHOD OF ANALYSIS.

The analytical methods employed were essentially those of the official chemists. The total solids were determined by mixing with asbestos and drying at 100° C. In a few cases it was found difficult to determine insoluble solids when the soluble solids were very slow to filter through the linen filter. The fruit sample began to jelly before it all passed through. Usually the determination was made without this difficulty. Acid was determined by titration against fifth-normal KOH, using phenolphthaleïn as indicator in the uncolored solutions; otherwise litmus paper was used. In clarifying the fruit solutions for sugar determination alumina cream was used in the analyses recorded in the tables on mango and papaya. In all other cases lead subacetate was used instead, since alumina cream proved inefficient in these fruits. Reducing sugars were determined by the volumetric Fehling solution method of Munson and Walker, the more acid fruit solutions being neutralized. Sucrose, with a few exceptions, was determined by Clerget's method. Fat was obtained by extraction with ether. When starch was known to be an especial constituent the total hydrolyzable carbohydrates were determined by acid hydrolysis. Diastase was used in the starch determination in studying the ripening of bananas and papayas.

ANALYTICAL DATA.

In the table on page 66 is shown the composition of several varieties of mangoes. The total solids are high for the average fresh fruit; the total sugars vary from 11 to 20 per cent, according to the variety. In all samples the sucrose is the principal sugar present. The protein in several varieties is a little higher than is usual in fruits. The acidity varies and is as much as 0.5 per cent in one variety.

Qualitative tests showed the presence of considerable amounts of tannin, but no starch was apparent.

The analysis of the avocado shows it to contain rather high total solids. The high percentage of soluble solids is probably due in part to oil which passed through the linen filter. The protein and ash are high for fruit. Very noticeable are the small amounts of sugars and the large amount of fat. The fat varies in the several varieties, being as high as 21.79 per cent in one fruit. The acid content of the fruit is very low.

As the composition of the banana is discussed more in detail later little need be said here about the analyses. They show the high and variable sugar content of the ripe banana, being highest in the baking varieties. The ash and protein are high. The acidity is low, being highest in the Apple banana.

The breadfruit is included in the table with bananas because it contains such high amounts of carbohydrates. In comparing it with the banana the hydrolyzable carbohydrates are seen to be much greater in amounts. The breadfruit contains considerable amounts of starch even when ripe. The ash, fiber, and protein are high.

The Samoan breadfruit was analyzed at a riper stage than the Hawaiian specimen, which may account for the larger proportion of starch to sugars in the former.

The jack fruit, belonging to the same family with breadfruit, and curious because of its huge size and strong peculiar odor, is rather high in protein and fiber and low in acid. The analysis of the total pulp shows less sugar than that of the edible portion, which consists of a yellow custard-like pulp surrounding each seed. The seed of the jack fruit has a very high content of starch and but very little sugar. The protein is over 5 per cent.

The composition of the papaya is discussed below in more detail. In comparing the several varieties the total solids are seen to vary several per cent.

The acidity and protein vary also with the variety as do the sugars. As experiments in breeding new varieties of papayas are being carried out by the horticultural department of this station to develop flavor, sugar, and firmness, these analyses are of interest as showing the changes brought about. It will be noticed that the principal sugar of the papaya is invert sugar, and only traces of sucrose are found.

Citrus fruits are known for their high acid content, which makes them especially refreshing when made into beverages. The common orange is milder than the lime or lemon, containing less acid and more sugar than the latter fruit. Sucrose and reducing sugar are both present in the orange.

The fiber is rather high in the oranges and shaddock. The high fat content in the limes and lemons may in part be due to oil from the skin. The samples were prepared by peeling off the skin in case of the orange and grinding up the whole pulp. The lemons and limes were squeezed as in obtaining the juice, which accounts for the low total solids found.

The samples of guavas analyzed were obtained by grinding up pulp and seeds together, as it is difficult to separate the seed. The skin was removed in all except the strawberry guavas, which are eaten whole.

The sugar content of the guava is not high. The strawberry guava contains more acid than the other varieties, but is less acid to the taste.

The sweet sop and cherimoya contain considerable sugar, principally reducing sugar. The protein and fiber are high and the acid low.

The roselle is of commercial interest, as it is used to a great extent in making jams and jellies which resemble cranberry jelly. The calyx is unusually low in sugars and hydrolyzable carbohydrates and quite high in acid. Its food value is almost nil, but its strong acidity, fine red color, and jellying qualities make it of especial value as a cooking fruit. The seed pods have a somewhat higher carbohydrate content and are less acid.

The tamarind is of interest because of its high acid and sugar content. It is supposed to contain more acid and sugar than any other fruit. The tamarinds analyzed in this laboratory were lower in reducing sugar than those grown in the Philippines, but the fruit may have been slightly green. The analysis reported by Pratt and Del Rosario[1] shows the green tamarind to contain little sugar, but the sugar increases very greatly on ripening.

In the analysis of the pomegranate, sample 1 was obtained by grinding up the pulp and seeds, but in sample 2 the seeds were separated from the pulp.

Of the Hawaiian berries the poha and Hitchcock berries are most commonly used. The poha makes a jam which has an unusually delicious flavor. The berries are quite acid. The ohelo grows wild on the mountain sides and is not cultivated to any extent. It has a low sugar and acid content. The Hitchcock berry is similar to the raspberry.

Prickly pear grows wild on the islands, but the red juicy fruit is not very popular as a food on account of the spines that make it difficult to pick. The fruit is juicy, sweet, and very mild in flavor.

Kamani fruit is used in making an alcoholic liquor, and is very fibrous.

The noni is a bitter fruit with a disagreeable odor; it is much used as a medicine.

Of the nuts analyzed the coconut and kukui are best known. The nuts contain considerable oil and but little sugar. The protein is high in the kukui and cashew nuts, but low in the coconut. The kukui is only eaten in small amounts, as it has a poisonous effect. The cashew requires baking before it can be eaten with impunity.

The table following gives the results of the analyses of 92 samples of Hawaiian fruits and nuts.

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[1] Philippine Jour. Sci., Sec. A, 8 (1913), No. 1, pp. 59–80.

Composition of some Hawaiian fruits, nuts, etc.

Kind of fruit.	Edible portion.	Waste.	Total solids.	Insoluble solids.	Ash.	Acids as H_2SO_4.	Protein.	Sugars.			Polarization.			Fat.	Fiber.	Hydrolyzable carbohydrates other than sucrose.
								Reducing.	Sucrose.	Total.	Direct.	Invert.	Temperature.			
Mango (*Mangifera indica*):	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	° *V.*	° *V.*	° *C.*	*Per ct.*	*Per ct.*	*Per cent.*
Pirie	60.00	40.00	20.52	3.14	0.343	0.221	0.456	3.55	11.23	14.78	+ 8.84	−5.45	31	0.032	0.508	....
Pirie	65.28	34.72	21.02	1.75	.466	.127	.838	3.31	14.02	17.33	+11.8	−6.10	30	.165	.404	....
Alphonse	67.48	32.52	20.92	2.42	.469	.373	.919	3.74	10.90	14.64	+ 9.7	−4.2	30	.149	.715	....
Oahu	61.66	38.34	19.61	3.82	.445	.122	.531	2.06	13.66	15.72	+12.4	−4.8	33.5	....	.713	....
Totafari	60.19	39.81	15.27	2.11	.277	.578	.475	3.55	7.93	11.48	+ 4.8	−5.2	33.5	.065	.539	....
Jamshedi	66.25	33.75	20.07	4.35	.415	.264	.944	1.53	11.53	13.06	+10.2	−4.4	32	.133	.656	....
Gay	59.60	40.40	23.42	4.02	.419	.379	1.075	3.01	16.99	20.00	+14.2	−7.2	33.5	.530	.695	....
Brindabani	69.75	30.25	19.75	5.88	.274	.269	.438	4.55	10.43	14.98	+ 8.0	−5.2	32.2	.126	.518	....
Avocado (*Persea gratissima*):																
Makaha I	74.57	25.43	21.01	10.43	1.003	.137	1.456	.83	.00	.83	+ 2.0	+2.4	31.4	13.05	1,282	....
Makaha II	73.47	26.53	25.87	13.97	1.031	.093	....	.64	.00	.64	+ 3.2	+3.2	31.5	17.25	1.378	....
Davis No. 7	64.57	35.43	21.29	13.78	.915	.069	2.094	1.28	.39	1.67	+ .5	.0	33	11.92	1.639	....
Davis No. 6	51.34	48.66	30.74	20.57	1.038	.078	1.700	.44	.00	.44	+ .2	+ .2	31.8	21.79	1.672	....
Davis No. 4	63.39	36.61	28.15	18.91	1.034	.104	2.238	.56	.00	.56	+ .6	+1.2	30.5	19.01	1.707	....
Banana (*Musa* spp.):																
Chinese	70.00	30.00	21.28	2.45	.955	.245	1.788	8.18	8.48	16.66	+ 7.9	−3.2	23.7	.180	.253	None.
Apple	74.49	25.51	31.52	....	.964	.417	1.238	14.56	9.59	24.15	+ 6.6	−5.6	31	.223	.351	....
Brazilian	68.25	31.75	27.78	7.21	.924	.406	1.775	17.23	2.45	19.68	− .9	−4.0	31.5	.201	.305	2.57
Baking	75.72	24.28	32.22	5.49	.750	.397	1.350	21.16	5.04	26.20	+ 1.6	−4.8	31.6	.518	.333	2.53
Fehi	64.29	35.71	27.87	10.30	....	.230	1.069	14.49	.00	[1] 14.49	....	....	....	.046	.594	....
Breadfruit (*Artocarpus incisa*):																
Hawaiian	77.75	22.25	41.82	20.35	.952	.049	1.575	1.75	7.74	9.49	+ 8.2	−1.6	32	.190	1.204	27.89
Samoan	83.44	16.56	26.89	8.44	1.152	.078	1.575	4.93	9.67	14.60	+10.4	−2.0	29	.517	.978	9.21
Jack fruit (*Artocarpus integrifolia*):																
Whole fruit	57.73	42.27	18.92	8.86	.962	.181	1.688	5.55	2.18	7.73	+ 1.6	−1.2	29	.599	1.904	....
Pulp	32.00	68.00	23.20	5.76	.934	.274	1.444	6.51	8.64	15.15	+ 7.5	−3.6	28.5	.450	1.311	....
Seeds	87.00	13.00	50.82	34.94	3.497	.162	5.444	.71	1.16	1.87	+ 1.9	+ .4	28.0	.241	1.609	23.53
Papaya (*Carica papaya*):																
Trinidad (2976)	75.56	24.44	12.14	1.66	.539	.061	.438	8.98	.74	9.72	+ 1.8	+ .86	31	.065	.780	....
South Africa (2973)	72.29	27.71	13.00	2.32	.549	.098	.681	10.20	.53	10.73	+ 2.4	+1.7	29.2	.074	.818	....
South Africa (2973)	73.50	26.50	14.06	2.52	.612	.098	.519	10.62	None.	10.62	+ 1.8	+1.76	33.4	.041	.851	....
Honolulu (2355: 3)	71.75	28.25	12.20	1.81	.560	.078	.500	10.29	None.	10.29	− .4	− .5	31.5	.059	.663	....
Barbados (2848)	84.11	15.89	11.72	2.44	.481	.069	.463	8.95	None.	8.95	+ .8	+ .86	32.5	.068	.765	....
Tahit (2975)	74.76	25.24	10.19	2.07	.677	.171	.906	7.50	.94	8.44	+ .7	− .5	31.5	.045	.789	....
Tahiti (2975)	78.14	21.86	9.50	1.90	.630	.113	.694	6.71	.39	7.10	+ .7	+ .2	30.0	....	....	....
Barbados (2764)	77.47	22.53	10.58	1.88	.517	.103	.731	7.47	.31	7.78	+ 2.0	+1.6	31.0	.055	.754	....

Barbados (2848)	82.44	17.56	9.22	1.99	.372	.078	.519	6.10	.31	6.41	+2.0	+1.6	30.8	.091	.842	....
Panama (2979)	47.71	52.29	16.51	1.78	.878	.186	.750	13.21	2.04	15.25	+1.0	−1.6	31.0	.115	1.003	....
Panama (2978)	48.58	51.42	14.41	2.09	.905	.147	.506	9.86	1.26	11.12	+1.8	+.2	30.5	.253	1.094	....
2355	83.39	16.61	10.59	1.05	.565	.059	.388	8.02	None.	8.02	−.2	.0	31.0	.186	6.693	....
Orange:																
Kona	72.13	27.87	12.15	2.57	.453	.882	.681	2.09	3.81	5.90	+3.5	−1.4	28.3	.387	.575	....
Waialua	70.50	29.50	9.56	2.60	.505	1.058	.819	4.25	2.99	7.24	+3.2	−.6	31.4	....	3.66	....
Japanese	71.26	28.74	11.20	2.16	.353	.749	.831	3.82	2.83	6.65	+3.0	−.6	30.6	.448	.479	....
Chinese	68.75	31.25	10.81	3.01	.522	3.758	....	....	....	....	....	....	....	.303	.777	....
Shaddock	42.39	57.61	11.53	6.14	.486	.196	1.175	.86	7.26	8.12	+7.6	−1.6	31.8	.140	1.977	....
Limes	49.17	50.83	11.75	.11	.352	6.830	.675	1.50	None.	1.50	−0.4	−.2	31.5	3.561	.065	....
Lemons (rough)	33.14	66.86	6.44	.30	.232	3.371	.356	1.53	.47	2.00	+2.2	+1.6	32.3	1.49	.084	....
Guava (*Psidium guajava*):																
Common	84.69	15.31	17.78	7.27	.531	.363	1.125	6.61	.77	7.38	−1.8	−2.8	30.2	.524	4.445	....
White	87.76	12.24	18.75	7.73	.676	.451	1.525	5.73	2.53	8.26	−.2	−3.4	32.3	.412	5.105	....
Trinidad	86.62	13.38	15.43	8.99	.651	.261	1.506	5.79	.55	6.34	−2.5	−3.2	31.0	.353	4.425	....
Guava (*Psidium cattleianum*):																
Chinese strawberry	98.01	1.99	20.08	7.36	.635	.696	....	3.64	6.37	10.01	+4.70	−3.4	31.0	.418	3.868	....
Common strawberry	98.60	1.40	18.27	9.97	.743	1.171	1.038	2.41	2.05	4.46	+1.8	−.8	31.7	.554	6.146	....
Common strawberry	81.16	18.84	23.75	14.47	.755	.715	1.838	2.32	3.31	5.63	+2.4	−1.8	32.0	.790	9.378	....
Fig: (*Ficus carica*):																
——— ———	80.39	19.61	16.96	2.85	.475	.127	.988	12.98	None.	12.98	−1.8	−1.6	31.6	.368	1.275	....
2384: 1	81.96	18.04	17.72	2.09	.548	.137	1.250	12.75	0.39	13.14	−1.5	−2.0	33.2	.210	1.149	....
Tantalus	78.34	21.66	10.27	2.18	.454	.167	1.963	6.28	None.	6.28	−.5	−.4	30.5	.261	1.073	....
Pineapple (*Ananas sativus*)[2]	....	....	....	....	....	.66	.375	3.92	6.78	10.70	+5.0	−3.6	31.7	....	....	....
Grape (*Vitis labrusca*):																
Isabella	56.25	43.75	15.73	6.67	.205	.490	.394	16.19	None.	16.19	−5.0	−4.8	28.7	.238	.289	....
Sweet sop (*Anona squamosa*)	53.47	46.53	21.33	4.07	.844	.215	2.038	16.51	None.	16.51	−3.4	−3.6	31.7	.547	1.632	....
Do	55.73	44.27	24.82	5.48	.673	.127	1.531	15.27	2.88	18.15	−.7	−4.4	27.7	.548	1.225	....
Cherimoya (*Anona cherimola*)	84.23	15.77	33.81	9.86	.669	.064	1.838	15.34	3.07	18.41	+.3	−3.6	31.4	.145	4.293	....
Star apple (*Chrysophyllum cainito*)	86.90	13.10	11.47	5.46	.392	.127	2.338	2.67	1.73	4.40	+1.6	−.6	31.5	1.385	.857	....
Mountain apple (*Eugenia malaccensis*)	73.87	26.13	8.61	....	.137	.068	.213	6.88	None.	6.88	−2.1	−2.1	29.0	.035	.562	....
Rose apple (*Eugenia jambos*)	62.94	37.06	15.85	3.70	.299	.039	.794	11.26	.47	11.73	−1.2	−1.8	30.3	.189	.982	....
Java plum (*Eugenia jambolana*)	57.50	42.50	15.63	3.54	.287	.838	.619	12.99	None.	12.99	−3.0	−2.8	32.7	.524	.164	....
Surinam cherry (*Eugenia michelli*)	84.38	15.62	9.30	1.93	.342	1.440	1.019	4.68	1.38	6.06	−1.0	−2.8	25.0	.664	.343	....
Loquat (*Eriobotrya japonica*)	60.00	40.00	10.02	2.71	.385	.666	.413	1.79	2.09	3.88	+.5	−2.2	27.5	.500	.653	....
Roselle (*Hibiscus sabdariffa*):																
Calyx	55.43	44.57	11.58	5.03	.651	2.263	1.231	.20	None.	.20	+.4	+.4	29.0	.819	1.454	1.57
Seed pods	....	....	23.73	16.91	1.078	.637	4.000	.27	1.09	1.36	+1.0	−.4	29.5	1.152	6.621	4.18
Ceriman (*Monstera deliciosa*)	73.88	26.12	22.12	2.12	.851	.353	1.181	16.19	None.	16.19	−4.4	−4.6	33.5	.205	.569	....
Natal plum (*Carissa grandiflora*)	78.12	21.88	21.55	4.29	.437	1.196	.563	12.00	None.	12.00	−5.6	−5.2	32.3	1.03	.918	....
Carambola (*Averrhoa carambola*):																
Sweet	100.00	None.	8.22	3.13	.421	.784	.719	3.40	None.	3.40	−.7	−.7	31.3	.755	1.237	....
Sour	100.00	None.	8.69	2.84	.408	.309	....	5.25	.16	5.41	−.6	−.8	29.5	.314	.992	....
Tamarind (*Tamarindus indica*)	48.28	51.72	69.51	17.68	1.823	11.329	3.431	18.74	2.58	21.32	+3.3	.0	31.2	.851	5.615	....
Pomegranate (*Punica granatum*):																
Whole fruit	56.06	43.94	26.33	10.14	.591	.122	1.488	12.21	None.	12.21	−3.2	−3.2	30.2	.477	5.297	....
Pulp	46.88	53.12	17.52	1.98	.735	.137	.525	15.00	1.07	16.07	−2.6	−4.0	30.0	.304	.329	....
Poha (*Physalis peruviana*)	100.00	None.	17.86	6.78	.733	1.009	....	2.67	5.97	8.64	+6.4	−1.2	30.7	.331	4.730	....
Do	100 00	None.	17.76	7.09	.829	1.214	2.006	2.25	5.49	7.74	+6.6	−.4	30.5	.298	3.828	....

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[1] Determined by copper reduction method.

[2] Hawaii Sta. Rpt. 1910, p. 47.

Composition of some Hawaiian fruits, nuts, etc.—Continued.

Kind of fruit.	Edible portion.	Waste.	Total solids.	Insoluble solids.	Ash.	Acids as H_2SO_4.	Protein.	Sugars.			Polarization.			Fat.	Fiber.	Hydrolyzable carbohydrates other than sucrose.
								Reducing.	Sucrose.	Total.	Direct.	Invert.	Temperature.			
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	° *V.*	° *V.*	° *C.*	*Per ct.*	*Per ct.*	*Per cent.*
Ohelo berry (*Vaccinium reticulatum*)	100.00	None.	8.51	....	0.175	0.485	0.431	3.42	0.32	3.74	− 1.2	−1.6	33.0	....	....	....
Hitchcock berry (*Rubus* sp.)	100.00	None.	13.22	7.01	.397	.534	1.300	5.48	None.	5.48	− .8	− .4	30.5	0.391	3.953	....
Liberian coffee (*Coffea liberica*):																
Pulp	....	....	28.21	13.34	1.630	.255	2.863	5.30	None.	5.30	+ .4	+ .4	31.9	.288	3.315	....
Bean	....	....	45.18	35.52	1.578	.069	5.338	2.56	3.94	6.50	+ 3.6	−1.4	31.6	.685	14.703	....
Prickly pear (*Opuntia tuna*):																
Red	78.96	21.04	16.54	2.40	.579	None.	.938	12.75	.55	13.30	+ .3	− .4	30.0	.240	1.296	....
Green	....	....	19.66	4.69	.404	.181	.981	13.42	None.	13.42	− 1.4	− .8	31.0	.232	2.791	....
Longan (*Nephelium longan*)	58.52	41.48	17.61	....	....	....	1.419	5.99	2.35	8.34	+ 1.0	−2.0	30.3	.452	.638	....
Allspice (*Pimenta officinale*)	100.00	None.	28.28	18.42	1.110	.392	1.581	11.09	None.	11.09	− 3.4	−3.1	33.8	2.033	4.040	....
Wi apple (*Spondias dulcis*)	65.00	35.00	14.53	2.48	.442	.478	.500	7.09	3.45	10.54	+ 1.3	−3.1	30.5	.286	.853	....
Hog plum (*Spondias lutea*)	47.50	52.50	11.47	.83	.655	.980	1.375	9.41	None.	9.41	− 1.5	− .8	29.7	.565	1.165	....
Kamani (*Terminalia catappa*)	63.94	36.06	19.52	8.62	.963	.162	.788	7.78	.94	8.72	− .4	−1.6	31.2	.229	3.300	....
Carryong (*Brachychiton* sp.)	36.84	63.16	13.78	2.21	.890	.715	1.525	1.31	7.72	9.03	+ 7.4	−2.4	31.3	.620	.808	....
Noni (*Morinda citrifolia*)	59.93	40.07	10.97	3.16	.838	.303	.631	3.37	.14	3.51	− 1.1	....	....	.260	1.052	....
Oil palm (*Elæis guineensis*):																
Fruit	49.76	50.24	28.70	....	....	.431	1.088	4.45	None.	4.45	− 1.2	−1.3	33.0	.258	8.907	....
Algaroba (*Prosopsis juliflora*):																
Meal	100.00	None.	92.51	50.17	3.535	.331	9.863	3.07	27.59	30.68	+26.4	−9.2	27.3	1.160	24.578	....
Coconut (*Cocos mucifera*)	26.40	73.60	54.66	31.43	1.020	.129	4.206	Trace.	6.41	6.41	+ 5.4	−2.8	29.5	33.406	5.450	....
Macadamia nut (*Macadamia ternifolia*)	....	....	92.99	72.14	1.622	.098	....	Trace.	2.67	2.67	+ 1.8	−1.6	30.6	66.730	1.920	....
Kukui nut (*Aleurites triloba*)	12.1	87.9	92.86	....	3.05	....	19.88	....	....	....	....	....	....	66.250	1.39	[1] 1.40
Cashew nut (*Anacardium occidentale*)	29.48	70.52	93.22	....	2.588	....	14.437	....	....	....	....	....	....	41.568	1.273	....

[1] Total hydrolyzable material.

STUDY OF THE RIPENING PROCESS OF THE CHINESE BANANA AND THE PAPAYA.

It is of considerable interest to compare the composition and ripening process of two such fruits as the banana and the papaya. The banana, grown in the Tropics and commonly known in the Temperate Zone because it stands transportation so well, is characterized by its high carbohydrate content. The papaya, not so well known in the North, resembles the average fruit which contains little nourishment but is of value for its high water content, fruit acids, and enzyms. The papaya is characterized by an enzym allied to pepsin, which is considered to be an aid to digestion.

In this study of the fruits a few microscopic tests were first made on the unripe and the ripe samples. The banana when green and tested for starch by iodin turned en masse to an intensely blue-black color, but when ripe only a few granules scattered here and there turned dark, showing the great decrease in starch on ripening. A test for tannin on cross sections of both the green and ripe banana, using ferric chlorid solution, showed tannin to be arranged in a narrow line around the outer margin of the fruit and along the three divisions that radiate from the center.

In contrast to the banana the green or ripe papaya showed with iodin no indication of starch to the unaided eye, except for an almost imperceptible circle where the stem had been cut from the fruit. Under the microscope a few grains of starch could be discerned in the fruit itself. There was apparently no tannin present in either the green or the ripe papaya.

The chemical analysis of the two fruits was made according to the official methods,[1] modified in a few instances, as stated below.

Sucrose was determined by polarization before and after inversion. Reducing sugars were determined according to the volumetric method of Munson and Walker.[2] In every case lead subacetate was used as a clarifying reagent.

Hydrolyzable carbohydrates were determined by boiling the substance with 200 cubic centimeters water and 20 cubic centimeters hydrochloric acid (specific gravity 1.125). Starch in the banana was determined by digestion with diastase and after filtration hydrolysis of an aliquot with hydrochloric acid.

COMPOSITION OF THE CHINESE BANANA.

A bunch of Chinese bananas was picked while the fruit was very green and slightly undersized and hung up in a room near the laboratory, where it was allowed to ripen. An analysis was made of the very green fruit at a period when the peel adhered closely to the flesh.

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[1] U. S. Dept. Agr., Bur. Chem. Bul. 107 (rev.).

[2] Ibid., p. 42.

When the remaining bananas showed a slight yellow tint, a sample was again taken for analysis. Another sample was analyzed when the fruit was entirely ripe.

The determination of reducing sugar made on the water solution of the entirely green banana presented some difficulty, as the sugar content was extremely low, and some gum, which could not be precipitated with lead subacetate, caused a greenish-yellow precipitate to form on boiling with the Fehling solution. This difficulty was overcome by boiling the sugar sample with 95 per cent alcohol, according to the method of E. M. Bailey,[1] filtering, and evaporating the alcohol from the solution, to which lead subacetate was then added and the reducing sugars determined.

The results obtained on the first bunch of bananas are given under "a" in the table on page 73.

As the banana forms a gummy mass with water, it is almost impossible to separate sugars entirely from the starch and other carbohydrates by means of water. In some analyses both starch and the hydrolyzable carbohydrates were determined in the whole sample without first extracting the sugars. It was found that sugars were somewhat decomposed on boiling with the dilute acid, so that an error occurred by this method and the total hydrolyzable carbohydrates found in the ripe fruit was less than the total sugars found in the water solution.

A second bunch of green bananas was therefore obtained and allowed to ripen for analysis. In the samples from this bunch the sugars were first extracted with boiling alcohol[2] and the starch and hydrolyzable carbohydrates determined in the residues. It was found by this method that the sugars could be separated rapidly from the banana, since alcohol does not form the gummy mass with the material as does water. The starch was not separated from the dextrins before treatment with diastase and subsequent hydrolysis, but a separate determination of gums, soluble in water, showed them to be present to the extent of 0.59 per cent in the green and 0.43 per cent in the ripe fruit. In the ripe fruit the determination of gums was made on the residue after extraction with boiling alcohol; and as the boiling alcohol may easily have extracted certain dextrins, there may have been a higher percentage of gums than determined. Under "b" in the table are shown the results obtained by extraction with alcohol.

The results from both samples show that the total solids decrease slightly during the ripening process. The insoluble solids are almost as high as the total solids in the green banana, but decrease very rapidly on ripening and in the ripe fruit amount to less than 3 per cent. The ash is high throughout and does not change appreciably. The acid content is but a few tenths of a per cent and appears to reach its maximum when the fruit is half ripe, after which it decreases. The protein is fairly high and remains constant.

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[1] Jour. Amer. Chem. Soc., 34 (1912), No. 12, p. 1729.

[2] E. M. Bailey, loc. cit.

Quite striking is the change in starch and sugars, during the process of ripening of the banana. When green, the starch is exceedingly high, amounting to about 20 per cent, while the sucrose and reducing sugars amount to a few tenths of a per cent. At the half-ripe stage, the sugars have increased several per cent and in about the same proportion that the starch has decreased. In the fully ripened stage the sugars have increased greatly and the starch has almost disappeared.

The hydrolyzable carbohydrates, other than starch or sucrose, are small in amounts.

Fat occurred in small quantities, increasing from 0.025 per cent in the green fruit to 0.180 per cent in the ripe. Fiber was also present in small amounts.

In the water solution after boiling, none of the usual tannin reactions were obtained. Tannin was, therefore, not determined.

COMPOSITION OF THE PAPAYA.

The papayas used for study were obtained directly from one tree, each on the day analyzed, and were chosen by the horticulturist, who is familiar with the indications of ripening fruit. The fruits were analyzed at the fully ripe stage and at several immature stages, the very green ones being quite undersized. Those which were analyzed five months before ripeness were about half the size of the mature papaya. The yellow tint does not appear in the fruit until about three weeks before full ripeness. As the fruit contained practically no starch according to qualitative test, this determination was not made, but the total hydrolyzable carbohydrates were determined by boiling the material with dilute hydrochloric acid solution and subtracting from the total the reducing sugars found in the water solution. The results are shown in the table on page 73.

It is at once seen that the total solids are low throughout the ripening process and increase as the fruit ripens. The insoluble solids are about 3 per cent in the green fruit and decrease to about 1 per cent in the ripe fruit. The ash, acid, and protein occur in small quantities and are quite constant. The fruit contains not more than a trace of sucrose. The reducing sugars in the green fruit, however, amount to over 2 per cent but increase rapidly as the fruit increases in size and approaches ripeness. The hydrolyzable carbohydrates are almost nil, and fat, fiber, and undetermined matter occur only in small amounts. It is logical to conclude, therefore, that, as the fruit when green has no store of carbohydrates upon which to draw, it must obtain its sugars by translocation from the trunk of the trees.

In comparing the banana with the papaya it is noted that the banana contains higher percentages of total solids, carbohydrates, protein, acid, and ash, and is altogether a more substantial fruit. It is of interest to note that the total solids decrease in the banana during the ripening process but increase considerably in the papaya. The banana contains large amounts of starch and other carbohydrates when green. It may, therefore, be separated from the tree at that time and on ripening still contain a normal amount of sugar due to the hydrolysis of its starch. In the papaya no such store of food is held.

It is also interesting to note that the banana contains sucrose and reducing sugars. The papaya, on the other hand, has practically no sucrose but considerable reducing sugars. The fat content is more constant in the papaya during ripening and the fiber is higher than in the banana.

In both fruits the acid-sugar ratio is low.

Some of the changes in the composition of the Chinese banana and of the papaya during the ripening process are shown in the accompanying table.

Composition of the Chinese banana and the papaya at different stages of ripeness.

Stage of ripeness.	Edible portion.	Waste.	Total solids.	Insoluble solids.	Ash.	Acids as H_2SO_4.	Protein.	Sugars.			Polarization.			Starch by diastase method.	Hydrolyzable carbohydrates other than starch or sugar.	Fat.	Fiber.	Undetermined matter.
								Reducing.	Sucrose.	Total.	Direct.	Invert.	Temperature.					
Chinese banana.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	° *V.*	° *V.*	° *C.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Green (a)	57.48	42.52	23.51	16.25	0.871	0.196	2.013	0.15	0.31	0.46	+ 1.6	+1.2	25.3	17.38	1.16	0.025	0.276	1.13
Green (b)	....	....	28.51	25.25	.891	.114	1.275	.10	.53	.63	+ .6	− .1	25.3	19.97	1.23	.055	.370	3.97
Half ripe (a)	63.64	36.36	21.98	10.78	.948	.343	1.838	4.93	4.17	9.10	+ 4.2	−1.2	26.2	5.02	2.28	.151	.335	1.96
Half ripe (b)	57.76	42.24	27.56	14.90	.921	.320	1.331	3.53	7.31	10.84	+ 6.8	−2.6	28.3	7.93	1.64	.091	.314	4.17
Ripe (a)	70.00	30.00	21.28	2.45	.955	.245	1.788	8.18	8.48	16.66	+ 7.9	−3.2	23.7	None.	None.	.180	.253	1.20
Ripe (b)	67.00	33.00	24.47	2.66	.883	.156	1.119	7.41	11.26	18.67	+10.4	−4.2	25.6	.43	.49	.257	.309	2.16
Papaya.																		
5 months before ripeness	71.00	29.00	6.48	3.28	.621	.065	.800	2.15	.23	2.38	+ 1.5	+1.2	30.7	....	.26	.205	.873	1.28
5–6 weeks before ripeness	80.97	19.03	6.13	2.38	.451	.045	.381	2.88	None.	2.88	+ 1.0	+1.2	28.0	....	.49	.186	.602	1.09
4 weeks before ripeness	81.24	18.76	6.13	2.31	.427	.045	.388	2.81	.23	3.04	+ .7	+ .4	27.8	....	.01	.188	.692	1.34
3 weeks before ripeness	81.13	18.87	6.26	2.46	.471	.026	.306	2.93	None.	2.93	+ .7	+ .8	26.7	....	.45	.208	.716	1.1
2 weeks before ripeness	78.73	21.27	6.45	2.49	.425	.044	.306	4.13	.47	4.60	+ .6	.0	31.0	....	.00	.261	.581	.23
8 days before ripeness	84.65	15.35	8.92	2.37	.508	.033	.356	5.99	None.	5.99	− .2	− .2	30.0	....	.12	.163	.654	1.10
1 day before ripeness	84.99	15.01	10.68	1.18	.514	.059	.463	7.82	.47	8.29	− .6	−1.2	27.5	....	....	.168	.592	.65
Entirely ripe	83.39	16.61	10.59	1.05	.565	.059	.388	8.02	None.	8.02	− .2	.0	31.0	....	.00	.186	.693	.68

E8

Issued June 23, 1916.

HAWAII AGRICULTURAL EXPERIMENT STATION,

J. M. WESTGATE, Agronomist in Charge.

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION.

1915.

UNDER THE SUPERVISION OF
STATES RELATIONS SERVICE,
Office of Experiment Stations,
U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1916.

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the States Relations Service, United States Department of Agriculture.]

E. W. ALLEN, *Chief of Office of Experiment Stations.*

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

STATION STAFF.

J. M. WESTGATE, *Agronomist in Charge.*
J. EDGAR HIGGINS, *Horticulturist.*
M. O. JOHNSON,[1] *Chemist.*
D. T. FULLAWAY,[2] *Entomologist.*
F. G. KRAUSS, *Superintendent of Extension Work.*
J. B. THOMPSON,[3] *Assistant Agronomist, in Charge of Glenwood Substation.*
ALICE R. THOMPSON, *Assistant Chemist.*
V. S. HOLT, *Assistant Horticulturist.*
C. A. SAHR, *Assistant Agronomist.*
A. T. LONGLEY, *Executive Assistant.*

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[1] Appointed July 25, 1915, to succeed Wm. T. McGeorge, transferred to U. S. Department of Agriculture, Bureau of Chemistry.

[2] Resigned June 30, 1915.

[3] Appointed July 6, 1915, to succeed F. A. Clowes, resigned.

LETTER OF TRANSMITTAL.

Hawaii Agricultural Experiment Station,
Honolulu, Hawaii, September 14, 1915.

Sir: I have the honor to transmit herewith and to recommend for publication a report of the Hawaii Agricultural Experiment Station, 1915.

Respectfully,

J. M. Westgate,
Agronomist in Charge.

Dr. A. C. True,
Director States Relations Service,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. True, *Director.*

Publication authorized.
D. F. Houston,
Secretary of Agriculture.

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REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1915.

SUMMARY OF INVESTIGATIONS.

By J. M. Westgate, *Agronomist in Charge.*

INTRODUCTION.

The station has continued as in the past to aid in the development of diversified agricultural industries in the islands. There are a number of crops that have been found agriculturally possible which at present are not able to compete economically with sugar, and the station has continued its experimental and extension work to place some of these on a profitable basis. It is felt that the most stable prosperity is that which is based upon a number of lines of industry rather than upon a single crop. To this end the station is collecting data as to the agricultural possibilities of different crops on the different soils of the various islands. As rapidly as possible the cultural requirements of these various crops in relation to soils, altitudes, and moisture supply are being worked out.

BUILDINGS AND GROUNDS.

During the year only minor repairs and additions were made in connection with the station buildings. The roofs of three of the buildings were treated with roof-preserving paint in order to prolong the life of the shingles. The foundations of the same buildings were also repaired where decay and insect pests had weakened or destroyed the timbers. It was found necessary to rebuild one of the large water tanks holding a reserve water supply of 60,000 gallons.

The Marine-Hospital Service tract of land adjoining the station grounds was resurveyed and laid out in plats for the department of agronomy. The survey indicated that there were about 3 acres available for cultivated crops. This ground was replowed and planted to corn, potatoes, and various green-manure crops.

Owing to the uneveness of the soil as well as to the high cost of water for irrigating, especially for rice and taro, the lease of the Wyllie Street tract was terminated at the end of the year. Arrangements have been made with private rice and taro growers for cooperative experiments along the same lines as those carried out on this tract, and at considerably less expense to the station.

Preliminary arrangements were made with the officers in charge of the Army reservations for the lease of a tract of 10 acres of land for the purpose of determining the possibility of forage production for the Army horses. The rainfall is somewhat limited, but it is expected that proper methods of tillage and spacing will make possible economical yields of certain species of forage grasses.

CHANGES IN THE STATION STAFF.

During the year a considerable number of changes were made in the scientific staff of the station. On January 1, 1915, E. V. Wilcox, special agent in charge, was transferred to Washington, D. C., and was succeeded by J. M. Westgate, who was transferred from the Office of Forage Crop Investigations, United States Department of Agriculture. D. T. Fullaway, entomologist, returned from his year's furlough on June 1, 1915, but resigned June 30, 1915, to accept a position with the Territorial Board of Agriculture and Forestry in connection with the search for parasites of the melon fly (*Dacus cucurbitæ*). W. P. Kelley, chemist, resigned October 27, 1914, to become professor of agricultural chemistry in the Graduate School of Tropical Agriculture and Citrus Experiment Station at Riverside, Cal. He was succeeded by Wm. T. McGeorge, formerly assistant chemist at this station. Mr. McGeorge in turn left the station June 30, 1915, on a transfer to the Bureau of Chemistry, United States Department of Agriculture. Mr. McGeorge's transfer, however, did not become effective until July 8, 1915. F. A. Clowes, superintendent of Hawaii substations, resigned June 30, 1915, to take charge of the agricultural department of the Lahainaluna Industrial School, where he will be retained as a collaborator of this station in order that he may attend to the work done in cooperation with that institution. F. G. Krauss was appointed superintendent of extension work beginning November 1, 1914. Mr. Krauss was formerly agronomist of this station, but had resigned to become professor of agronomy at the College of Hawaii, which position he was filling at the time he was appointed to take charge of the extension work of this station. J. de C. Jerves was appointed collaborator January 1, 1915, at Homestead, Kauai; John E. Gamalielson, April 1, 1915, at Hilo, Hawaii; and John McCoy, May 1, 1915, at Kamuela, Hawaii, to assist in the extension work among the small farmers of those sections. George Copp was appointed collaborator January 1, 1915, at Waiakoa, Maui, but resigned June 30, 1915.

TERRITORIAL MARKETING DIVISION.

The Territorial legislature at its 1913 session appropriated funds for the maintenance of a marketing division for Hawaiian-grown products and the station was given supervision of the project. Not a little of the satisfactory results of the work of the marketing division has been due to the loyal support of the local newspapers and other agencies and individuals interested in the upbuilding of the lesser agricultural industries of the islands.

During the year the division has made a large increase in the amount of produce handled, the sales amounting to $69,182.50 against $26,095.10 for the preceding year. The consignments which have been received have generally been in better condition than formerly, but there is yet much to be done in educating the shipper to pick, grade, and pack his products properly.

Practically all Hawaiian agricultural products except sugar have been handled by the division, most of them successfully. The onion crop harvested this year met a very poor market due to the large hold-over supply of 1914 mainland onions. Prices on the mainland were so low that it did not pay to ship our early Bermuda onions, but fresh pineapples, bananas, Maui beans, and a small shipment of copra have brought good returns.

The division has continued to publish and distribute to the producers of the Territory the Weekly Market Quotation Sheet. This sheet gives the current wholesale quotations on island products and keeps the farmer in touch with the condition of the market. This sheet is also published by most of the papers of the Territory. Growers generally do not realize the importance of keeping the division posted as to the amount of produce they have to send to market and when it may be expected to arrive, but there has been considerable improvement in the past few months. It is safe to say that the producer has received better prices since the division was established than ever before, whether he marketed his produce through the division or elsewhere.

Up to the present time the division has been seriously handicapped due to the poor facilities for handling such a large assortment of products as has been sent in for sale. With the appropriation of $14,400 for a new building and equipment made by the last legislature and an appropriation of $1,000 a month for the ensuing biennium for general expenses, most of the present difficulties should be overcome. The last legislature also filled a pressing need when it appropriated $7,500 to be used as a revolving fund for buying seed and crates to be resold to the farmers and for making advances on consignments. This fund has made it possible for the division to supply the growers with crates in which to ship their pineapples to the mainland without requiring payment for the crates until returns are received for the fruit.

Due to the apparent overproduction of pineapples in Hawaii and the prospect of a large portion of the 1915 crop rotting in the field for want of a purchaser at a price less than half the cost of production, the division opened a branch office in San Francisco to sell fresh pineapples and such other products as find a better market on the mainland than at home.

HORTICULTURAL INVESTIGATIONS.

Horticultural investigations have continued along lines similar to those of recent years.

The litchi (*Litchi chinensis*) has received considerable attention. The excellence of this fruit, its high price, and its apparent adaptability to Hawaii have commended it for further investigations. The high price of the fruit is due to the limited supply and its popularity, not only among the Chinese, who are most familiar with this fruit, but also among all classes of the population. One of the reasons for the limited supply lies in the slowness of the methods of propagation in vogue, while another cause may be found in the great tardiness of seedling trees in coming into bearing. Experiments are being conducted to facilitate more rapid propagation by asexual means in the hope of overcoming both of these difficulties. Considerable progress has been made along these lines.

Attention has also been given to the preservation of the fruit for short periods in refrigeration, and also to various methods of transporting the seeds, which, under ordinary conditions, retain their viability only a few days. No deterioration in appearance or flavor of the fruit has been noted during refrigeration for the short periods which were tried. Other experiments along these lines are necessary. It was found possible to ship the seeds by mail in sphagnum moss, seeds having been sent by this means from Honolulu to Florida, where they are reported to have arrived in excellent condition.

In the mango investigations some studies have been made of the flowers and of the technique of cross-pollination. Bark grafting has been applied to the mango with considerable success, thus adding one more means for the top-working of established mango trees with choice varieties. Some of the new varieties of mango are not only superior to the common strains, but are more resistant to the Mediterranean fruit fly.

Some observations have been made of the keeping qualities of the Macdonald variety of avocado. Fruits were kept in the horticultural laboratory for 16 days without any refrigeration, and at the end of this time were in a perfect state of preservation. Bark grafting was tested on the avocado, but proved not to be so successful as scion budding, which consists in the inserting of the scion in a T-shaped incision in the bark of a mature branch.

Further pollinations of the papaya have been made, and lines of close-breeding as well as cross-breeding have been started.

A number of experiments have been made in the cross-pollination of two species of Aleurites, *A. moluccana*, the ordinary kukui of Hawaii, and *A. fordii*, known as the Chinese wood-oil tree. There are 120 fruits set, which are the result of these crosses, unless it may prove that some of them represent parthenocarpic or parthenogenetic developments.

The distribution of seeds and plants has been continued, chiefly with the varieties that have been under investigation, such as hibiscus, papaya, citrus, mango, and avocado.

ENTOMOLOGICAL INVESTIGATIONS.

On account of the absence of the entomologist for 11 months of the year, but little station work along entomological lines was accomplished. The insect collection was maintained, however, and a number of requests for assistance in combating insect pests were complied with either by personal visits or by advice as to the best methods of procedure. It had been anticipated that the entomologist while on furlough to the Territorial Board of Agriculture and Forestry, would be able to locate effective parasites for the pink bollworm of the cotton plant, but it was deemed inexpedient to assign him to this particular problem. Studies concerning the life history of the pink bollworm of cotton were made by August Busck, of the Bureau of Entomology, United States Department of Agriculture. Mr. Busck was given use of the insectary and entomological laboratory to facilitate the prosecution of his investigations.

CHEMICAL INVESTIGATIONS.

The relative value of the different forms of phosphate fertilizers has been determined in a series of pot experiments with three types of Hawaiian soils. The crops used were Japanese millet, cowpeas, buckwheat, radishes, and turnips. The results indicate that bone meal or other difficultly soluble phosphates are of little value as fertilizers in most parts of the Hawaiian Islands, since the soil already contains a large quantity of insoluble phosphate. For the best returns the phosphoric acid should be used in the form of soluble phosphate and in light applications at frequent intervals. The insoluble phosphates are of little value except in the wet districts. In soils high in iron and alumina, lime has in the past been added with applications of soluble phosphates in order to delay the formation of iron and aluminum phosphates. It has been found, however, that plants fertilized with iron and aluminum phosphates have made very satisfactory growth.

Organic phosphorus in rice was found to be present in the form of phytin. Since the phytin occurs in unpolished rice and rice bran, but not in the polished rice, it is evident that the phytin is normally present only in the outer layers of the rice grain.

This station has been a persistent advocate of the use of legumes for green manuring for many years. Pot cultures have been made with 32 species of legumes. In one series of pots the entire plant has been turned under in order that the humus value and amount of nitrogen added may be determined. In the second series the nitrogen fixed by the plants has been determined. It was found that the nitrates in pots where legumes had been grown were much lower than in the check pot, but after removing the plant and allowing the pot to stand in the open the amount of nitrates soon equaled that in the check pots. Lime was found to be necessary for the best growth of the legumes.

Arsenite of soda has had quite an extensive use as a weed destroyer. In soil which had been sprayed with this chemical the arsenic was found to have accumulated in the top 4 inches of soil. The use of such sprays in excessive amounts should therefore be avoided.

The peculiar character of Hawaiian soils makes necessary some modifications of the ordinary methods of soil analysis. The experience in soil analysis on the part of the various chemists employed at this station has been summarized, and a modified method of analysis has been prepared and is given in the body of this report.

A bulletin of the station entitled "The Soils of the Hawaiian Islands"[1] gives the results of six years' work on Hawaiian soils, together with the practical application of the results obtained. Successful soil management requires deep plowing, followed by frequent shallow cultivations. Because of the heavy clay character of the soils and consequent danger of "puddling," the maintenance of the humus content by rotation of crops and green manuring is essential for the best results. Proper drainage is also important. In general, both nitrogen and phosphoric acid give good results as fertilizers. Soluble phosphates are recommended except in wet districts. Where there is a heavy rainfall the insoluble phosphates are best. Under similar conditions organic and ammoniacal nitrogen are better than the nitrate.

AGRONOMIC INVESTIGATIONS.

The principal crops experimented with during the year were rice, taro, corn, potatoes, cotton, millet, as well as various forage grasses and legumes. In a liming and fertilizer test the yield of shelled corn was greatest on the plat receiving lime only, the same having been applied at the rate of 1,100 pounds per acre.

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[1] Hawaii Sta. Bul. 40 (1915).

In an experiment to determine the effect of soil aeration on yields of rice it was found in the first experiment that 308 pounds more per acre was obtained from the aerated than from the nonaerated plat. The second test showed 680 pounds per acre in favor of aeration.

In a preliminary test for determining the effect of aeration on yields of taro the taro itself showed a slightly increased yield, while the "hulis" (offsets) showed a considerable increase on the aerated plat.

In a spraying test with Bordeaux mixture and lime sulphur for potato fungi on Early Rose potatoes the plat sprayed with Bordeaux produced at the rate of 30.2 bushels, as compared with 25.9 bushels for the lime-sulphur spray and 15 bushels per acre for the check.

In the tests of legumes for green manuring jack beans and velvet beans are among the most promising.

In an alfalfa yield test the ordinary alfalfas were found to outyield both the Peruvian and Turkestan varieties.

The sorghums constitute a very promising class of green forage crops, some averaging as high as 15 tons per acre, with the cutting 90 to 100 days apart.

Of the forage grasses Sudan grass is easily the most promising for general use throughout the islands. The fondness of the birds for seed of this grass makes the problem of seed production a difficult one. The station plats are protected with bird-proof nets.

Interesting results were obtained from Japanese millet. Yields as high as 12 tons of green forage, 3 tons of roughage, and 30 bushels of seed per acre have been obtained. Plantings of this crop are most satisfactory when made in November and December and harvested in January and February, the time of year when sorghums are not making rapid growth.

Numerous distributions of seed from all the more promising grasses and leguminous forage crops, as well as other field crops, have been made to farmers having facilities for making tests and increasing the available seed supply of the particular species in question.

AGRICULTURAL EXTENSION.

The extension division was definitely organized in November, 1914, although considerable extension work had been in progress before that date. The work centers in part in the substations referred to elsewhere in this report and in part in the various extension activities, such as demonstration farm work, trips to various stations on the part of extension workers, assistance at agricultural fairs, fostering of boys' and girls' agricultural clubs, together with field demonstrations of improved means of crop production on private farms under the general supervision of the extension agents. It is felt that a great deal of good has been accomplished as a result of the voluminous correspondence with persons who have written to the station asking for advice and information concerning their more pressing agricultural problems. One of the most serious problems in connection with the extension work is that of providing for the large amount of travel that appears to be necessary if the agents are to keep in touch with the various individuals they should reach. Travel by water to a number of places is possible only by boats that make the call at rather infrequent intervals. On land the distances between the different sections are often such as to make automobile service essential in the interests of time economy. The commercial charges are such as to make it impossible to use such service except in cases of extreme emergency. It is true that a great many individuals have their own automobiles and willingly place them at the disposal of the extension agents for the visit to their places. Those who most need the services of the extension division, however, are seldom in a position to provide transportation of any kind.

SUBSTATIONS.

Owing to the withdrawal of Territorial funds, it was found necessary to abandon the various substations with the exception of that at Glenwood, which was continued on a greatly decreased allotment, a part of which came from private subscriptions. The banana work at Hilo, however, was continued under the supervision of the superintendent of the Glenwood substation. The extension funds of the station have made possible the employment of several collaborators who devote portions of their own farms to demonstration work and use the results obtained as a basis in part for extension work among the farmers they are able to reach. Work of this kind is under way at Haiku, Maui; at Hilo, Hawaii; at Kamuela, Hawaii; and at Kalaheo homestead, Kauai. At Hilo the collaborator is chiefly concerned with the development of improved methods of butter making in order that the product may compete more successfully with butter imported from the mainland. At Kamuela a typical homestead is being conducted by the collaborator at that place. He is making a number of trials of various crops to determine which are economically practicable under the local conditions. For instance, it is found that, while a considerable number of fresh green vegetables can be produced, it does not seem profitable to ship them to Honolulu, owing to the long haul to the wharf, the high freight rate, and the rough treatment often accorded such shipments because of the necessity of transferring the shipments from small boats to the steamers, which are unable to reach the wharf. It therefore seems advisable for homesteaders in such sections to raise pigs and poultry and such crops as can be marketed in a dry condition and in quantity. At Kalaheo homestead the collaborator has given considerable attention to the extension of the poultry industry throughout his immediate section. He has also become interested in the possibilities of starch production from cassava, and a number of his neighbors are planting considerable acreages. At the present time the starch is selling for 7 cents a pound. At Haiku both extension work and demonstration work are under way on a comparatively large scale, and a separate report of the work of this station, as well as of that at Glenwood, appears in this report.

This station maintains what is essentially a substation on the slopes of Mount Tantalus at an elevation of about 1,000 feet. The station reservation includes all the land between the Tantalus substation and the station plats at the lower end of the tract, but most of the intervening land is uncleared and in this condition is not suitable for experimental work. At the upper station there are under test and observation numerous species of plants which do not thrive at lower altitudes. The principal crops under test are bananas, coffee, rubber, avocado, Chinese wood-oil nuts, Macadamia nuts, citrus trees, and roselle.

GLENWOOD SUBSTATION.

The reduction of the Territorial allotment for the work of the Glenwood substation materially handicapped the work of the station during the entire year, only the bare maintenance and a few other essential expenditures being possible. In spite of this handicap, which necessitated material curtailments in its activities, much good has resulted from the continued operation of the station. The dairy herds of the entire section have been improved by the utilization of the herd bull, while the sale of eggs for hatching from the station poultry flocks has materially improved many of the flocks throughout the islands. The introduction of such grasses as *Paspalum dilatatum* and the demonstration of the best methods of utilizing the native honohono have been of much assistance to the small farmer, who is largely dependent upon his herd of live stock for a livelihood. In addition to the actual work of the substation itself, the superintendent has taken an active interest in a large number of agricultural activities concerning which his advice and assistance were sought and apparently much appreciated.

NEEDS OF THE STATION.

There are several pressing needs of the station to which it is desired to call attention. At the station itself the services of a plant pathologist are needed. There are a number of plant diseases which manifestly lessen the production of several of the island crops which would otherwise be much more profitable. Among these may be mentioned potato blight, late blight of celery, a banana disease of somewhat obscure nature, a root rot of taro, and several other diseases which are not conspicuous simply because the crops which they attack are not at present being grown to any considerable extent on account of economic conditions prevailing in the islands. It is highly desirable that as complete information as possible be obtained concerning the best methods of controlling such plant diseases as now stand in the way of extensive production of the crops affected.

Hawaii presents, within limited areas, a greater diversity of climatic and soil conditions than can be found in an area of the same size in any part of the mainland of the United States. Within 3 or 4 miles the rainfall may vary from a few inches to 10 or 12 feet per year. The changes in altitude on the rapidly ascending mountain slopes cause changes in temperature varying from strictly tropical to that of the region of frost and snow. This great diversity gives rise to regional limitations of adaptability. Pineapples, for example, prosper at certain altitudes where there is sufficient rainfall. Coffee likewise flourishes at certain altitudes and under certain conditions of soil and rainfall, but elsewhere is a failure. Hence it becomes necessary that many of the problems pertaining to crop production be worked out in the localities typical for each crop. It is important that there should now be a pineapple substation where the problems of this industry, second only to sugar cane in value, might be worked out.

As another particular instance it may be mentioned that at Schofield Barracks there is a great need of forage for the Cavalry horses and work mules. At present hay has to be brought from the mainland at large expense for freight alone. There is available on the reservation probably sufficient ground to grow all the roughage required when once the proper varieties and cultural requirements have been determined. It has therefore been recommended that a local substation be established on the tract in question where the practicability of growing suitable grasses or other forage can be definitely determined.

It is therefore recommended that as fast as funds will permit there be established substations in the sections where crop problems are most pressing, and where the potential importance of the crops in question is sufficient to justify such an expenditure.

PUBLICATIONS.

During the year the following publications were issued by the station:

Annual Report for 1914.
Bulletin 35, Absorption of Fertilizer Salts by Hawaiian Soils.
Bulletin 36, Grasses and Forage Plants of Hawaii.
Bulletin 37, Ammonification and Nitrification in Hawaiian Soils.
Bulletin 38, Effect of Fertilizers on the Physical Properties of Hawaiian Soils.
Press Bulletin 47, Cold Storage for Tropical Fruits.
Press Bulletin 48, Suppression of Weeds Among Pineapples by Arsenite of Soda Spray.
Press Bulletin 49, A Cheap and Effective Home-made Plank Drag.
Press Bulletin 50, The Effect of Arsenite of Soda on the Soil.

REPORT OF THE HORTICULTURAL DEPARTMENT.

By J. Edgar Higgins.

The work of the horticultural department has been continued along lines similar to those of recent years. During the first part of the year the horticulturist was absent from the office, having reported for duty in Porto Rico at the close of a year's leave of absence. The latter part of June of the last fiscal year was spent in investigations of the fruit industries of Porto Rico, and the early part of the present fiscal year in travel in Cuba and Florida. The purposes of this travel were to observe horticultural conditions and progress in the countries visited with a view to the improvement of horticultural practices in Hawaii. The results of these investigations have been prepared for presentation in a separate report (see p. 58).

THE EXTENSION OF THE LITCHI.

The litchi, *Litchi chinensis* (*Nephelium litchi*), is now attracting considerable attention, not only in Hawaii (see Pl. I, fig. 1), but also in Florida and southern California. It appears probable that this fruit tree is adapted to a wider range of conditions than has been supposed. The excellence of the fruit and its very high price in Honolulu (60 to 75 cents a pound), due to the limited supply, makes it worthy of more attention. Considerable data have been accumulated during the year on methods of propagation, preservation of seeds, fruiting age, cultural methods, etc., which are being brought together in a separate paper. This station is cooperating in experiments in Florida and California with this species. A large number of seeds has been shipped to Florida in the pursuit of this work, and also as an experiment in transporting these short-lived seeds. About 50 pounds of fruit was shipped to the Office of Foreign Seed and Plant Introduction, in Washington, D. C., as a further means of testing the possibilities of the shipment of seeds and fruits. The shipment went in refrigeration as far as San Francisco and thence by ordinary express, icing being impossible with so small a quantity. The fruits are reported to have arrived in good condition.

On July 5 another small lot of fruit was placed in the fruit room of the United States Army transport *Thomas* at Honolulu en route for San Francisco. These were removed from refrigeration by the writer before arrival in San Francisco. They were in perfect preservation, apparently having lost nothing in flavor and appearance. Part of the seed was sent by mail in moist sphagnum moss to Washington, D. C., and part was distributed in localities of California, where it is hoped this species may succeed. All of this seed germinated well, demonstrating that it was not injured by refrigeration, and, further, that this is one of the means by which litchi seeds may be transported where refrigeration for fruit is available.

THE MANGO.

A number of interesting facts have been observed in the mango studies. Some preliminary studies have been made on the flowers of certain varieties and on methods of pollination. In the Alphonse variety, for example, it was found that a very large proportion of the flowers of the lower (inner) portion of the cluster was staminate. These staminate flowers have but one fertile stamen and four staminodes. They are unisexual by the abortion of the pistil, which sometimes may be detected in its aborted condition. These staminate flowers, while most abundant in the lower part of the lateral clusters, are also found throughout the entire cluster except near the outermost end of the central axis. The hermaphrodite or perfect flowers are found in all parts of the cluster, but chiefly near the termination of the lateral branches and of the central axis. At the base of the lateral clusters there are very few. These hermaphrodite flowers have but one stamen and one pistil, with four staminodes. The pistil is without any marked enlargement at the stigma.

The pollen of all the varieties of mango studied was found to be very small and almost colorless. In the few cross-pollinations which were made the ruptured anthers were brought into immediate contact with the flower being used as the female parent. This appeared to be a more practical means than any attempt to gather minute pollen grains and apply them with a brush.

PREMATURE FLOWERING.

Several mango seedlings less than 9 months old which had been grafted by inarching were found to be producing flower clusters above the point of union. In most cases the scion also was flowering, but in one case only the seedling stock. The mango tree ordinarily does not flower until it is from 5 to 6 years old, and the flowering of young seedlings less than a year old is quite beyond any observations that have been made here, and, so far as the writer is aware, no such cases have been previously recorded. Of 27 seedlings grafted to the Pirie, 4 produced flower clusters on the scions only, and 5 produced flowers on both seedlings and scions; of 5 grafted to the variety Brindabani, 1 produced flowers on the scion and on the seedling stock, and 1 produced flowers on the seedling stock only, with none on the scion. That is to say, 18 per cent of the plants grafted to Pirie and 20 per cent of those grafted to Brindabani formed flowers on both scions and stock. There is, of course, nothing remarkable in the production of flowers on the scions. It is very common to find scions producing flowers from flower buds which have been matured on the tree before the removal of the scion, but flowers on seedling mango stocks less than 1 year old are worthy of note.

No cause can be ascribed for these phenomena except the grafting. It is true that the seedlings had been cut back slightly to induce growth in the scion, but this injury to the top of seedlings frequently occurs. Possibly the unusual results may be accounted for by the influence of the scion upon the stock, and it will be noted that in all cases save one the scions flowered as well as the stocks. In this one exception, the scion showed the scar of a flower cluster of the last season at its terminus. The mere mechanical injury brought about by grafting and the constriction resulting from the tightening of the raffia bands should also be taken into consideration. Plate I, figure 2, shows some of the trees referred to bearing their flowers.

BUD MUTATION.

Instances of bud mutation have not been commonly reported in the case of the mango. An instance apparently illustrating this phenomenon has recently received attention. Several trees grown from seed of the variety locally known as No. 9 have all produced fruits of the general type. A single branch of one of these trees, however, produced a pink fruit (the No. 9 is green), rather smaller in size than the regular type, but otherwise resembling the variety from which it was grown.

BARK GRAFTING.

The bark grafting of the mango, which has been successfully applied by the Porto Rico Experiment Station, has been tested under Hawaiian conditions during the year. It has proved to be well adapted to the work of top-grafting established trees and is one more method available in this work. One of the great advantages of the method is its extreme simplicity. Bark grafting, which has been so commonly used in Hawaii on hibiscus, consists in the cutting of a scion with one bearing surface and inserting the same under the bark of a branch which has been cut back for the purpose (Pl. II, fig. 1). Branches of the stock may be selected from 1 inch to 3 or 4 inches in diameter, at a time when the bark is slipping. This feature is extremely important, as it is also when budding the mango. This condition of the bark usually occurs when the terminal buds are just beginning to burst open. A single straight slit about 5 inches long is made in the bark where the branch is cut off. The best scions are of rather small, well-matured wood of the last flush, and the end of the flush is preferable. Such scions are cut with one straight cut, giving a single bearing surface to be placed next to the cambium of the stock. The scion must then be securely tied in place with a strong tie, because the mango bark is thick, and if it begins to dry out it will break a weak strand. The whole scion and the top of the branch used as a stock must then be covered with a paper sack which has been dipped in warm wax. The sack is then tied close to the stock. This covering prevents excessive transpiration of moisture from the scion, which otherwise would be exhausted before a union could take place. The covering may be removed in about three weeks. From 50 to 75 per cent of the scions so inserted, under favorable conditions, may be expected to grow.

With this method available, as well as others which have been described in earlier reports and bulletins, there certainly is no good reason for continuing to allow vigorous trees to produce the worthless fruits which many now yield. The common Hawaiian mango is so inferior to some of the newer varieties that for this reason alone it should be largely replaced. The fact that the Hawaiian variety is so extremely subject to attacks of the Mediterranean fruit fly that few fruits escape, is a further reason for reducing the number of this variety and substituting the Pirie or other resistant varieties.

THE AVOCADO.

The avocado is one of the few fruits that is attacked by the fruit fly to so slight a degree that the injury is practically negligible from the standpoint of fruit production, although the pest has interfered with the marketing of this fruit on the mainland of the United States. Hawaii, however, has been of assistance to the mainland in the establishment of the avocado industry there, the results of most experimental work in Hawaii being of use in Florida and southern California. Many of the Hawaiian seedlings suffered severely in the frost of southern California in the winter of 1913. Some, however, the Nutmeg, for example, have shown considerable resistance to cold. Among the Hawaiian seedlings which are attracting attention in California are the Solano and the Meserve.

The Macdonald, the parent tree of many of the round, hard-shelled winter seedlings, has attracted some attention this year by its remarkable keeping qualities. Fruits were kept in the horticultural laboratory for 16 days without any refrigeration, and at the end of this time were in a perfect state of preservation. These winter fruits are most promising because of their season, and the hard-shelled character is greatly in their favor.

PROPAGATION EXPERIMENTS.

The method of bark grafting applied to the mango has also been tested on the avocado, but has not, up to the present time, proved satisfactory. Scion budding, however, which is quite similar in character, has given satisfactory results. This consists in inserting a scion in a T-shaped incision in the stock. The stocks used for this purpose have been from 1 inch to 4 inches in diameter. The T-shaped incision is made in the same manner as for shield budding, but is much larger. The scion consists preferably of a short piece at the end of a branch from a mature tree which is not growing too rapidly (Pl. II, fig. 2). This scion is prepared by a single cut, and is inserted in the incision, bringing one surface only into contact with the cambium of the stock. It is then tied in place and waxed with a firm grafting wax which will not run when heated by the sun.

This method of propagation appears to have two points in its favor. It affords a means of propagating from old bearing trees which frequently do not produce good bud wood unless they are severely cut back and forced to do so. Scions, however, may be taken from the terminals of slow-growing branches on which there is no material for ordinary shield budding. A further point in favor of the method is that it can be used to work into branches of considerable size, whereas for shield budding it would be necessary to cut back the stock and await the growth of new shoots in which to insert the buds. It is not intended to imply that this method is preferable to shield budding even for top-working trees, but that it may be rendered serviceable under certain conditions.

MULTIPLE-STEMMED SEEDLINGS.

It is a well-known fact that many avocado seeds send up numerous stems. It has been suggested that some of these might be the result of multiple germs. All the multiple-stemmed seedlings which have been studied up to the present time have indicated that there has been a single central stem and the others have arisen from buds on this stem beneath the surface of the ground and in many cases within the seed.

THE PAPAYA.

The work of the breeding of papayas was resumed along the lines indicated in earlier annual reports and in a bulletin of the station.[1] There are no conclusions of special moment to report at present. A number of crosses and close pollinations have been made to secure information on questions arising in earlier work. It is very interesting as well from a practical as from a scientific point of view to

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[1] Hawaii Sta. Bul. 32 (1914).

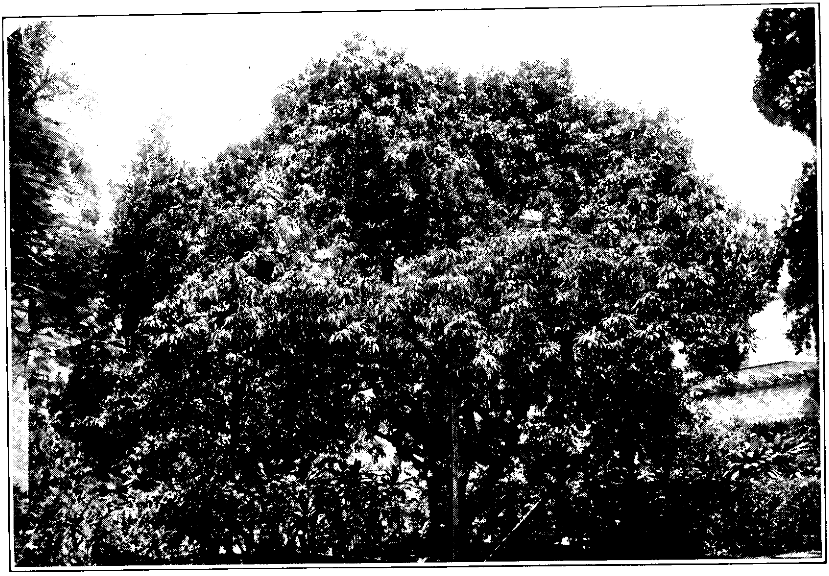

FIG. 1.—HONOLULU'S OLDEST LITCHI TREE.

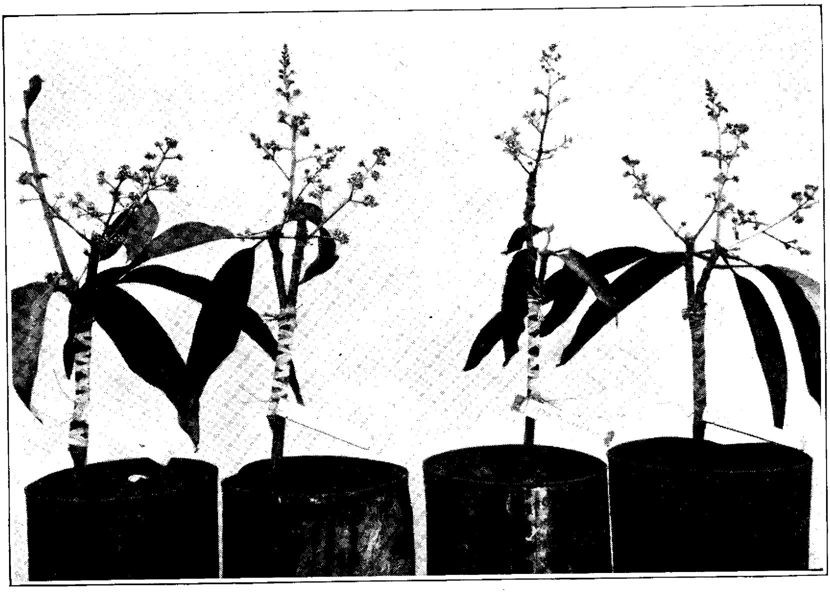

FIG. 2.—MANGO SEEDLINGS IN FLOWER, LESS THAN 9 MONTHS OLD.

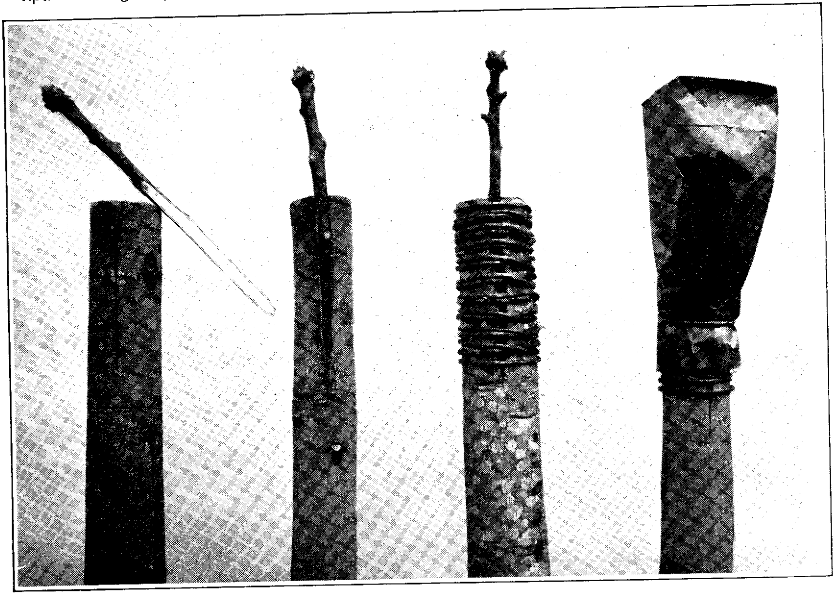

FIG. 1.—BARK GRAFTING THE MANGO.

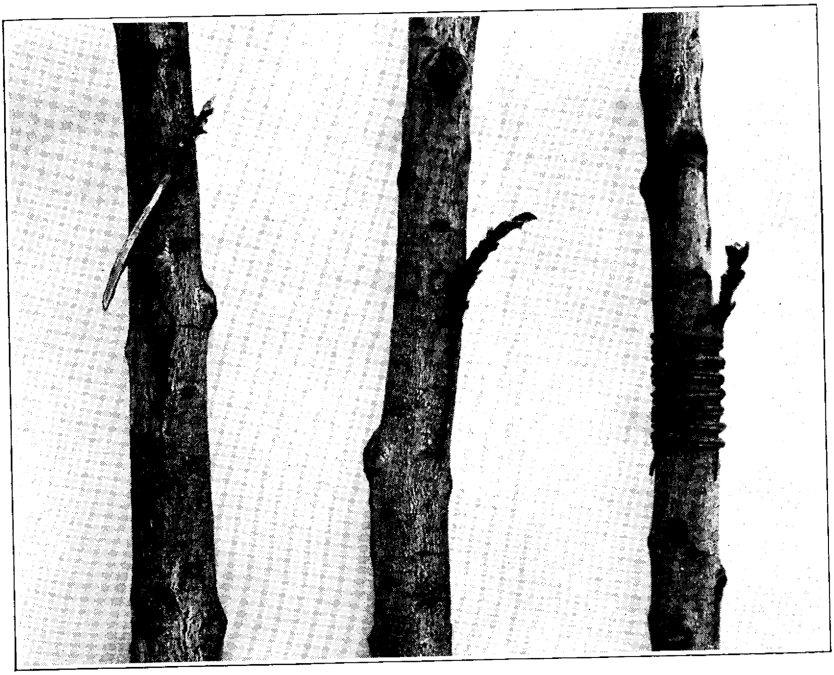

FIG. 2.—SCION BUDDING APPLIED TO THE AVOCADO.

learn what are some of the factors determining sex in a species producing both diœcious and hermaphroditic stocks. Will the pollen from a hermaphrodite flower produce offspring that will be almost exclusively fruit bearing, either pistillate or hermaphrodite? To throw light on this and related questions, pollinations have been made as follows:

Flowers of pistillate trees of diœcious stocks have been fertilized with pollen from hermaphrodite flowers of the elongata form. Flowers of pistillate trees of the hermaphroditic stock have received pollen from staminate trees. Pistillate trees of diœcious stocks again have been fertilized with pollen from hermaphrodite flowers of the pentandria forms, both oval and pyriform. The possibility of perfecting such fertilizations had in most cases been determined in earlier experiments, but the sex of the progeny has not yet been observed.

A series of close pollinations also has been begun, wherein hermaphrodite flowers of elongata form have received their own pollen exclusively, the purpose being to initiate close breeding.

A number of cross-pollinations also has been made with a view to determining, if possible, and combining unit characters pertaining to flavor, keeping qualities, uniformity in shape, and bearing habits.

CITRUS ORCHARD.

In the citrus orchard many varieties are now in bearing and making a satisfactory growth. Practically all these varieties have been introduced as bud wood and have been worked upon home-grown stocks, thus building up a supply of all the leading varieties of orange, lemon, lime, and grapefruit. A limited amount of bud wood of the following varieties, now bearing, is available: Oranges—Bahia, Bouquet des Fleurs, Golden Buckeye, Golden Nugget, Mediterranean Sweet, Navelencia, Ruby, Scented, Thompson, Valencia, Dancy, King, Willowleaved, and Satsuma; pomelos—Duncan, Imperial, Marsh, McCarty, Royal, and Triumph; lemons—Eureka, Genoa, Lisbon, Ponderosa, and Villafranca; and limes—Kusaie and Tahiti.

WOOD OIL AND KUKUI.

The commercial possibilities of the oil of kukui, *Aleurites moluccana* (*A. triloba*), and of the China wood oil, *Aleurites fordii* (*A. cordata*), have recently attracted considerable attention. It is claimed by some manufacturers that a blend of these two oils is preferable to either. It has been suggested that the hybridizing of these species might result in new forms that might combine the desired characters in a way superior to either of the parents. In bearing habits the China wood-oil tree appears to be quite inferior to the kukui, which bears in clusters, while the Chinese tree produces usually only one nut at the end of each branch, where there is ordinarily found one pistillate flower surrounded by several staminate flowers.

Mr. Valentine S. Holt, assistant horticulturist, was requested to attempt the hybridizing of these species. From 37 cross-pollinations, in which *A. fordii* was used as the female parent, 26 fruits are now set. On *A. moluccana* there are 94 fruits, the flowers of which received pollen from *A. fordii* only. In neither case has it yet been proved that parthenocarpic or parthenogenetic development does not occur in these species, but it appears probable that there is an affinity between them which may be ultilized in hybridization.

DISTRIBUTION OF SEEDS AND PLANTS.

A large number of valuable grafted and budded fruit trees have been distributed to different parts of the Territory, and some have been sent to the mainland and to foreign countries. These have consisted chiefly of mango and avocado, with a few lemons, limes, oranges, and grapefruit. Except in case of exchange, it has been the custom to make a charge for these to cover in part the cost of propagation and handling. By reason of a recent act of Congress, all money now received from sales of products reverts to the Treasury of the United States and does not become available for the use of the experiment station. It thus becomes impossible to recover expenditures made in propagation. For this reason and because other funds are not available, it will be necessary largely to discontinue this work, except as it relates to the introduction and establishing of new and unusual varieties.

The same applies even more strongly to the distribution of hibiscus cuttings. The new varieties of these ornamentals which have been originated here have been distributed in numbers aggregating hundreds of thousands at a nominal charge and may now be seen in all parts of the Territory, while they add to the beauty of many tropical lands. These flowers of rare and delicate beauty will be an asset to the Territory far exceeding all that they have cost. The time has come, however, when the future distribution of the plants and cuttings should be put on a commercial basis.

It has become necessary greatly to reduce the number of hibiscus plants at the experiment station, the land, and more particularly the water, being required for other plants. One plant of each of about 500 or 600 varieties, however, will be retained, while the others will be placed along the public highway at Army posts and public parks where they will benefit the largest number of observers.

Papaya seeds of the varieties bred here have been distributed to a large number of applicants. This will be continued in conjunction with the breeding work.

Seeds of various other economic plants have been distributed, among which may be mentioned roselle, *Carissa grandiflora*, Annonas, Carambolas, and star apples.

Bud wood of citrus varieties has also been sent wherever it has been requested.

EXTENSION WORK IN HORTICULTURE.

The knowledge of budding and grafting is not so general here as in countries where there is large commercial orcharding. Through various methods of extension work, the art is being taught which will make of more service the large collection of varieties at the station. Assistance was given by instruction and demonstration at the summer school for teachers. A trip was made by the horticulturist to the island of Maui, chiefly in the interest of this work. Another trip was made to Hilo to assist in the county fair. The horticulturist is now acting in an advisory capacity in connection with the present effort of the Territorial marketing division to place Hawaiian pineapples in the mainland markets in much larger quantities than heretofore, and thus relieve the situation of the growers who are unable to dispose of their crop.

NEEDS OF THE HORTICULTURAL DEPARTMENT.

The greatest needs of the horticultural department of this station at present are land and other facilities for culture experiments with pineapples and bananas. These are the two fruits of commercial importance for export, and at present they are the only fruits that are allowed entrance from Hawaii to the mainland markets. There is great need for field experiments with both of these crops, but none of the land at the experiment station furnishes normal conditions for them. It is hoped that funds may be made available for the leasing of a suitable tract of land upon which to begin this work.

REPORT OF THE ENTOMOLOGICAL DEPARTMENT.

By D. T. FULLAWAY.

The entomologist of the station was absent on leave from July 1, 1914, to May 31, 1915. During this time he was in the employ of the Territorial Board of Agriculture and Forestry, being engaged in the prosecution of the general campaign development of parasites of the Mediterranean fruit fly, a work which has met with considerable success.

The close proximity of these two stations to one another made it possible for the entomologist to keep his office open at the Federal experiment station and to attend to his routine work of correspondence and maintenance of the insect collection, which was greatly increased by material obtained from abroad.

During the month of June, 1915, most of the entomologist's time was spent in studies in connection with *Sierola* spp., the natural parasites of various species of Lepidoptera.

While the repeated absences of the entomologist from the station in connection with the Territory-wide insect parasite campaign has to some extent interfered with the work of independent investigation, it is believed, however, in view of what has been accomplished, that the agricultural interests of the islands have been better served than they would have been had the entomologist remained at the station engaged in individual work with parasites of the insect enemies of the agricultural and horticultural crops, or in other lines of entomological activity.

REPORT OF THE CHEMICAL DEPARTMENT.

By WM. T. MCGEORGE.

During the past fiscal year Dr. W. P. Kelley resigned as head of the department to become professor of agricultural chemistry at the Graduate School of Tropical Agriculture and Citrus Experiment Station at Riverside, Cal. The work of the chemical department has proceeded with little interruption along the same lines as outlined in previous reports.

The investigation of scientific soil problems, having a very practical significance in the islands, has received the continuous attention of the staff, while all miscellaneous routine analyses have been made with as little interruption of the above work as possible. Marked progress has been made toward a thorough understanding of the peculiar properties, both physical and chemical, of Hawaiian soils.

FIXATION OF FERTILIZERS.

During the fiscal year 1914 experiments on the fixing power of Hawaiian soils were completed, and the results were issued during the past year as a bulletin of the station.[1]

Due to the highly basic character of these island soils, the fixation of phosphoric acid is much higher than that of the other elements. The results show that the best method of application of the phosphates is just before planting. The soluble form should ordinarily be used.

The fixation of potash is apparently controlled by the amounts of lime and magnesia present, and is quite marked. Some loss by leaching is possible, however, if the potash is applied in too large quantities.

With ammonia nitrogen, while the point of saturation is higher, the fixation is not so strong as that of potash. Soils rich in humus retain the ammonia and also the potash better than the red clay type. This is probably due to interaction with the complex "humates."

The Hawaiian soils retain little, if any, of the nitrogen in the form of nitrate. Some highly organic soils, however, react with and fix some of the nitrate solution. Air drying, heat, and the use of antiseptics have little influence on the fixing power of the soil.

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[1] Hawaii Sta. Bul. 35.

BACTERIOLOGICAL INVESTIGATIONS.

The results obtained by Dr. Kelley in the study of bacterial action in Hawaiian soils were published during the year as a bulletin of the station.[1]

Due to the unusual character of the Hawaiian soils, the decomposition of organic nitrogen compounds into forms available for plant food is of considerable importance. The lime-magnesia ratio as influencing nitrification being a subject of much controversy, an investigation was made of the effect of magnesia on nitrification.

Observations show that nitrification does not take place in most Hawaiian soils unless oxidizing conditions are maintained by tillage. Besides aeration, virgin soils also require weathering for several months before the nitrifying bacteria will become active.

The effect of heat and antiseptics was also investigated. Partial sterilization probably makes available, through alterations in the colloidal film, new stores of food and organic material to the surviving organisms, and thus stimulates bacterial action. The effect of aeration also is partly due to the same cause assisted by granulation and oxidation.

The lime-magnesia ratio does not seem to be of much importance in Hawaiian soils. Magnesium carbonate favored ammonification, while calcium carbonate stimulated nitrification in some instances. Dolomitic and calcareous limestone will probably produce similar effects on the availability of the nitrogen in Hawaiian soils.

For any system of permanent agriculture on Hawaiian soils, rotation of crops, including green manuring, must be strongly insisted upon in order to maintain the best aeration possible.

PHYSICAL STUDIES OF HAWAIIAN SOILS.

In another bulletin issued during the year,[2] the results are given of an extensive study of the physical properties of Hawaiian soils and the effect of fertilizers on these properties. Since it is impossible to measure by chemical analysis the presence of a normal application of fertilizer in the soil, and since it has been shown that the addition of salts and fertilizing materials affects the structure of the soil materially, it is suggested that these measurements of the physical effects of applications of fertilizer would be of considerable importance in determining the value of the fertilizer salts.

In most instances the fertilizer salts increase hygroscopic moisture, lower vapor pressure, and increase the cohesion of the soil particles. Capillarity is diminished in clay soils but increased in sandy soils by the addition of salts. Fertilizers increase the resistance to percolation, which takes place most rapidly in sandy soils.

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[1] Hawaii Sta. Bul. 37.

[2] Hawaii Sta. Bul. 38.

SOIL SURVEY.

Previous to the resignation of Dr. Kelley, a paper entitled "The Soils of the Hawaiian Islands" was prepared and submitted for publication as a bulletin of the station.[1] In this bulletin the work of about six years' investigation upon Hawaiian soils is taken up, dealing with the composition of the various types of soil found on the islands and the practical bearing and application of the various scientific investigations which have been carried on in this laboratory.

THE ORGANIC PHOSPHORIC ACID OF RICE.

It has been known for some years that phosphoric acid exists in grains in organic combination with inosite and some base, and, as such, is taken into the animal system as a supply of phosphoric acid to the body. Because of its physiological value, the organic phosphoric acid which is known as phytin or phytic acid has received considerable attention, and a number of investigators have studied its composition and occurrence in grains.

It was believed that a study of phytin in rice would be of interest, since rice is one of the principal crops raised in Hawaii, and is valued as food by many of the inhabitants. The isolation and study of the composition of the phytin in rice was made by Miss Alice R. Thompson, assistant chemist, and the detailed results have been published elsewhere.[2] It was found that most of the phytin in rice exists in the outer layer of the grains, and in the process of polishing the rice practically all the phytin is removed. Phytin was isolated from unpolished rice and from bran, but none could be obtained from polished rice. The total phosphorus was determined in the samples and found to be 2.29 per cent in the rice bran, 0.321 per cent in unpolished rice, and 0.140 per cent in polished rice.

The phytin was obtained by treating the sample bran and unpolished rice with 0.2 per cent hydrochloric acid and precipitating with barium hydroxid. The white barium salt was washed, dissolved, and reprecipitated several times with barium chlorid and alcohol. The composition of two samples of the tribarium salt was determined and the barium, phosphorus, carbon, and hydrogen contents compared with that of the tribarium-inosite-hexaphosphate salt reported by Anderson in other grains.

Special attention was paid to several methods of determining barium in the salt, and precautions were noted to be observed in obtaining a pure barium sulphate precipitate from solutions of the salt.

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[1] Hawaii Sta. Bul. 40 (1915).

[2] U. S. Dept. Agr., Jour. Agr. Research, 3 (1915), No. 5, pp. 425–430.

Inosite was insolated from the barium phytate and its melting point determined.

THE EFFECT OF ARSENITE OF SODA ON THE SOIL.

The increased use of arsenite of soda spray as a means of killing weeds led to a study of the injurious effect of this chemical. Attention was given to its influence upon plant growth, on the biological and physical properties of the soil, and its chemical action toward the soil constituents. The soils studied were found to have a very strong fixing power for arsenic. A sample of soil from Nahiku, Maui, on which weeds had been sprayed for five years at the rate of three sprayings per year (5 pounds arsenic per acre per application) showed on analysis that all the arsenic was held in the top 4 inches of soil. Accounts of this work have been published.[1]

THE AVAILABILITY OF PHOSPHATES.

This work, also mentioned in the last annual report, has been completed and submitted for publication as a bulletin of this station. It was broadened considerably more than was at first anticipated in order to study phosphates more thoroughly from all angles. The availability of all the commercial phosphates was compared; the solubility of phosphates naturally occurring in Hawaiian soils was studied; the fixation of phosphoric acid by the soil received some attention; and, finally, as an appendix, a modified method for determining phosphoric acid in local soils was submitted. The latter method was adopted after nearly 250 phosphate determinations.

The importance of the above work is realized when it is known that the phosphate content of Hawaiian soils is, with rare exceptions, ample for good plant growth, but owing to its extremely unavailable condition the addition of this type of plant food as a fertilizer is often desirable.

LEGUMES AS GREEN MANURE.

This station has consistently advocated the use of legumes as a green manure. The benefit derived from legumes is due to both chemical and physical effects on the soil; the nitrogen content is increased and the texture of the soil is improved by the added humus. The red clay Hawaiian soils, especially, need green manure to prevent puddling and to aid aeration.

In order to determine the relative value of the various legumes, pot experiments were made by Miss Alice R. Thompson, assistant chemist. One hundred and thirty-two pots were filled with a calcareous soil and the same number with a lime-poor soil. Thirty-two varieties of legumes were grown, one variety being apportioned to four pots of each soil type. Four pots of each soil were thus left as checks. At maturity the duplicate plants in two of the four pots were removed, weighed, and the nitrogen determined. Nitrates, nitrites, ammonia, and total nitrogen were determined in the soil and compared with the check pots, after deducting the nitrogen added in the legume seed. Two pots were left of each variety of legume planted, the plants being turned under to decompose. The quantity of nitrogen added to the soil will be determined later.

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[1] Hawaii Sta. Press Bul. 50 (1915); U. S. Dept. Agr., Jour. Agr. Research, 5 (1915), No. 11, 459–463.

In all instances the nitrates in the soil from which the legumes had been removed was much lower than in the check soil. But these soils low in nitrates on standing in the open air soon equaled in nitrate value the soil of the check pots. Where much legume material was turned under the nitrates in the soils were greatly increased.

The plants grown in soils deficient in lime made a poor growth and had a lower nitrogen content, calculated on a water-free basis, than the plants grown in soils rich in lime. In a second experiment lime was added to the lime-poor soil, but the plants grown in this soil were also undersized and low in nitrogen. In a third experiment phosphate fertilizer was added to the lime soil and plants again grown in these pots. Results are to be obtained in a few months from the last series.

THE ANALYSIS OF HAWAIIAN SOILS.

In the course of the examination of about 600 soil samples in this laboratory peculiarities in soil types have been met which necessitated slight modification in the method of soil analysis as outlined by the Association of Official Agricultural Chemists. Chief among the inhibiting factors may be mentioned the high content of iron, aluminum, titanium, and manganese.

The modifications found to produce best results are submitted herewith, as are also some data showing the influence of time upon the solvent properties of hydrochloric acid. It was hoped that, in view of the low silica content, the time of digestion could be shortened to advantage without lowering the thoroughness of the extraction.

Four soils were chosen for this work—a sandy soil (No. 1), a red clay (No. 2), a silty soil of high humus content (No. 3), and a brown clay (No. 4). These soils were digested on the steam bath with hydrochloric acid (specific gravity, 1.115) for 1, 4, 6, 8, 10, and 15 hour periods. The results are given in the table following.

Effect of time of digestion of soil in hydrochloric acid (specific gravity, 1.115) on thoroughness of extraction.

Soil No.	Time.	Insoluble. residue.	Iron oxid.	Alumina.	Titanic oxid.	Manganomanganic-oxid.	Lime.	Magnesium oxid.	Potash.	Sulphur trioxid.	Phosphoric acid.
	Hrs.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	1	45.30	15.04	9.64	1.36	0.22	3.39	8.74	0.19	0.26	1.09
	4	48.12	16.44	9.21	1.41	.30	3.09	....	.58	.21	.90
	6	38.06	16.36	14.79	1.61	.17	3.09	10.60	.62	.22	1.05
	8	37.10	16.80	14.44	1.71	.23	3.27	11.50	.72	.25	.96
	10	37.98	16.94	13.53	1.76	.17	3.58	10.50	.82	.35	.99
	15	37.61	17.80	13.33	1.76	.18	3.21	11.10	.75	.32	.99
3	1	37.24	9.08	10.90	1.07	.12	3.52	.91	.62	.35	2.35
	4	34.83	9.20	13.89	1.07	.11	4.00	1.02	.45	.34	2.31
	6	34.41	9.72	14.51	1.12	.12	3.76	.97	.41	.32	2.28
	8	34.15	9.44	14.91	1.12	.12	3.69	1.03	.52	.38	2.39
	10	34.30	9.88	14.73	1.12	.20	4.14	1.11	.58	.35	2.29
	15	34.38	9.72	14.55	1.07	.13	3.90	1.02	.59	.38	2.26
2	1	45.05	14.92	12.35	.78	3.03	.52	.28	....	.26	.27
	4	35.58	16.16	20.83	.97	2.81	.54	.32	.26	.27	.37
	6	32.90	15.36	24.03	1.02	2.89	.52	.34	.38	.23	.32
	8	31.38	16.08	25.25	1.02	2.48	.58	.58	.44	.26	.44
	10	30.89	16.52	25.94	1.07	2.53	.65	.57	.43	.29	.42
	15	29.93	17.40	25.01	1.07	2.63	.63	.59	.53	.28	.50
4	1	46.10	24.64	10.67	3.12	.04	.26	.74	.11	.19	.53
	4	38.77	29.92	11.48	3.90	.04	.30	1.05	.16	.22	.43
	6	34.59	30.00	11.96	4.19	.04	.30	.94	.20	.21	.40
	8	35.89	32.64	11.72	4.19	.07	.42	1.23	.23	.24	.36
	10	35.88	30.44	13.34	4.19	.08	.36	1.21	.22	.22	.50
	15	35.05	31.60	13.07	4.19	.04	.41	1.30	.26	.26	.51

As previously mentioned, it was hoped that a reduction in the time of digestion could be made for local conditions, but apparently best results are obtained by digesting for 10 hours. However, the conclusion is plainly evident that the use of hydrochloric acid of this strength is primarily a study of solution and not of ultimate composition, when applied to Hawaiian soils. A digestion of 10 hours by no means results in a complete extraction in all soils.

MODIFICATION IN ANALYSIS.

ACID DIGESTION.

Digest 10 grams of soil for 10 hours in a 300-cubic centimeter soil digestion flask with 100 cubic centimeters of hydrochloric acid (specific gravity, 1.115) in boiling water. Dilute with 50 cubic centimeters of water, filter while hot into a 500 cubic centimeter volumetric flask, and wash the residue until the filtrate is nearly 500 cubic centimeters. Cool to room temperature and make to volume (solution A).

INSOLUBLE RESIDUE.

Dry the insoluble residue and ignite to constant weight.

IRON, ALUMINUM, AND TITANIUM.

Take 50 cubic centimeters of solution A, add a few drops of nitric acid, boil for a few minutes, remove from hot plate, make slightly alkaline with ammonia, and boil off the excess. Filter, wash several times with hot water, and transfer the precipitate and filter to the original beaker. Dissolve by boiling in dilute hydrochloric acid. Reprecipitate as before, filter, and wash free of chlorid. Dry, ignite, and weigh the precipitate as ferric oxid, alumina, titanium oxid, and phosphorus pentoxid. Reserve the filtrate (solution B) for determining manganese, calcium, and magnesium.

Treat a second aliquot of 50 cubic centimeters of solution A in the same way up to the point of ignition of the ammonia precipitate. Instead of igniting, transfer the precipitate to the original beaker and dissolve by boiling in dilute sulphuric acid. Transfer to a 100-cubic centimeter volumetric flask, cool, and make to volume. Determine the iron by titrating 25 cubic centimeters of this solution with tenth-normal potassium permanganate in the regular way. Determine titanium by the colorimetric method as follows: Transfer 5 cubic centimeters of the sulphuric-acid solution to a 50-cubic centimeter Nessler tube, dilute, and add 5 cubic centimeters of dilute sulphuric acid, 5 cubic centimeters of hydrogen peroxid, mix well, and compare with a standard prepared at the same time from a solution of titanium sulphate. The filtrate from the second aliquot should be reserved for the determination of sulphate, soda, and potash (solution C).

Since potassium permanganate oxidizes titanium as well as ferrous iron, it is necessary to calculate the volume of permanganate required to oxidize the titanium present and to make a correction accordingly in calculating the iron. The aluminum is determined as usual by difference.

MANGANESE.

Concentrate solution B to about 150 cubic centimeters, add about 3 cubic centimeters bromin (undiluted), allow to stand 5 minutes, add an excess of ammonium hydrate, and heat to boiling. Let stand overnight, filter, wash with hot water, dry, ignite, and weigh as mangano-manganic oxid (Mn_3O_4).

CALCIUM.

Evaporate the filtrate to dryness and drive off the ammonium salts. Dissolve the residue in dilute hydrochloric acid and determine calcium in the regular way. The removal of the large excess of ammonium salts is necessary in order that any unprecipitated manganese will be thrown down.

MAGNESIUM.

Magnesium may be determined by precipitation in the regular way from the above filtrate direct.

SULPHATES.

Best results have been obtained by removing the iron and aluminum previous to the precipitation of the sulphate. Hence, solution C is evaporated to dryness, ammonium salts volatilized, the residue dissolved in dilute hydrochloric acid, and the sulphate determined in the regular way with barium chlorid.

POTASH AND SODA.

From this point the analysis may be carried out on the above filtrate according to the official methods without modification.

PHOSPHORIC ACID.

To 50 cubic centimeters of solution A add a few drops of nitric acid and heat to boiling. Make alkaline with ammonium hydrate, boil off excess, filter, and wash. Transfer filter and contents to a beaker and boil with dilute nitric acid, nearly neutralize with ammonia, add 50 cubic centimeters of molybdate mixture with constant stirring, and allow to stand in water bath for four hours at 55° C. From this point proceed as in the official method.

HUMUS.

Modifications in the method of determining humus are dealt with in full in a press bulletin of this station.[1]

SOIL COLLOIDS.

Frequent mention has been made in previous publications of this station of the presence of colloids in Hawaiian soils. A condition which apparently arises through the formation of this class of bodies was given some attention during the past year.

The clay soils may be divided into two classes: Class 1, in which the alumina is higher than the iron and the titanium is very low; and class 2, in which the alumina is lower than the iron and the titanium is high. The former class is the one showing the more colloidal properties, and in spite of this contains fewer clay particles than the latter class. In the analysis of the hydrochloric-acid extract, considerable difficulty arises upon filtering the ammonia precipitate of iron, aluminum, and titanic hydrates and phosphates. The inhibiting factor presents itself in the form of a colloidal gel, rendering the washing of the ammonia precipitate extremely difficult. This gel is insoluble in cold acids, and hence in redissolving the precipitate it is necessary to boil it in an acid solution.

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[1] Hawaii Sta. Press Bul. 33.

A sample of this colloidal gel was analyzed with the following results:

	Per cent.
Silica (SiO_2)	1.04
Phosphoric acid (P_2O_5)	1.02
Manganomanganic oxid (Mn_3O_4)	.73
Titanic oxid (TiO_2)	.66
Ferric oxid (Fe_2O_3)	9.37
Aluminum oxid (Al_2O_3)	87.18

Apparently this colloid is aluminum hydroxid, the physical properties of which are influenced by a small amount of silica and titanium. In all soils which contain iron in excess of alumina, this colloidal gel is never formed, but in soils of high aluminum content it is invariably present.

THE EFFECT OF PARTIAL STERILIZATION ON PLANT GROWTH.

Considerable study has been devoted to the effect of partial sterilization upon Hawaiian soils. A previous publication[1] treats of the effect of heat upon the physical and chemical properties of the soil, while the biological influences are thoroughly dealt with in the bulletin referred to on page 30.

During the year the above work has been supplemented by pot experiments. Heretofore the influence of sterilization on plant growth has been demonstrated in an experimental way in Hawaii only in districts where brush, accumulated in clearing land, has been burned upon the soil. In these cases a remarkable influence upon plant growth has been noted.

The pot experiments were carried out as follows: Two types of soil were used, a red clay and a sandy soil high in organic matter. These soils were treated as follows: Heated in sunlight, in an oven at 80°, 110°, and 165° C., and in an autoclave at 10 pounds pressure. Those heated in the oven were left for 2 hours, that in the autoclave for only 1 hour. In addition soils were treated with the following antiseptics at the rate of 10 cubic centimeters per kilogram: Carbon bisulphid, chloroform, and toluene. Also a check was run with the above in which the soil fresh from the field, that is, undried in the air, was used. These pots were planted in duplicate to onions, millet, and cowpeas.

The influence upon plant growth is well shown in the accompanying illustration. (See Pl. III.) The plants as shown are three months old.

The above illustrations represent plant growth upon the sandy soil. The results upon the red clay soil, while different in certain instances, as a whole are very much the same. A very poor stand was obtained in all the pots of red clay soil, for which reason no illustrations are submitted.

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[1] Hawaii Sta. Bul. 30 (1913).

ONIONS.

The influence of partial sterilization upon onions was very marked. Volatile antiseptics produced a wonderful increase, while heating in the autoclave was productive of a substance evidently toxic toward this plant. (See Pl. III, fig. 1.)

MILLET.

An increase in vigor of the millet plant was correlated with an increase in temperature at which the soil was sterilized. The plants are more vigorous in the pots sterilized by heat than those sterilized by antiseptics. It appears that the organic substance having a toxic influence upon onions is without effect upon millet, for in the pot heated in the autoclave, the plants are as vigorous as any others. (See Pl. III, fig. 2.)

COWPEAS.

In case of cowpeas, the increase in temperature at which the soils were sterilized resulted in a steady decrease in vigor. While the volatile antiseptics lowered the vigor to a slight extent, their influence is not so marked as heat. These results clearly show the intimate relationship between leguminous plants and bacterial life in the soil. (See Pl. III, fig. 3.)

REPORT OF THE AGRONOMY DEPARTMENT.

By C. A. Sahr.

The work of this department consisted largely in the continuation of the lines followed in previous years. The unusually long droughts handicapped the agronomic work on fields not provided with irrigation facilities.

Repeated failures with both sweet and field corn on the station grounds clearly demonstrated the necessity of an adequate irrigation system to insure this crop against irregular seasons when grown outside of the corn belt of the islands. While many insects attack corn, the damage they do is nominal if the plant is grown under favorable conditions. As soon as the crop becomes checked in growth by drought and the whipping action of heavy winds, insect attacks render the crop unprofitable even as silage.

A fertilizer and rotation test with Reid Yellow Dent corn No. 901 was begun, the crop being planted October 1, 1914, and harvested January 9, 1915. The results were so contradictory that no generalizations can be made from them.

SOIL AERATION TESTS WITH RICE AND TARO.

Experiments to ascertain the effects of soil aeration between crops upon the actual yields of submerged crops were conducted with rice and taro.[1]

The plat under test was divided, one-half being given a deep plowing early in June to allow aeration of the soil until the time of planting, while the remaining half or check plat was left untouched until plowed September 2. Both plats were planted to rice September 4, 1914, and the resulting crop harvested December 8, 1914. The aerated plat yielded 83.5 pounds of rice paddy as compared with 71.5 pounds on the nonaerated portion.

A second test, to serve as a check upon the first, was conducted on the same plats. However, the order of the plowing was reversed, the aerated plat of the first test serving as a check plat under the second test. Owing to the late maturity of the previous crops, the aerated plat had but 30 days over the check plat. Both plats were planted to rice on February 18. Here again the yield on the aerated plat was the greater, 96.25 pounds of rice paddy being harvested from the aerated plat and 78.5 pounds from the nonaerated one.

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[1] For results of a study of the effects of aeration on ammonification and nitrification in Hawaiian soils see Hawaii Sta. Bul. 37 (1915).

In the soil aeration tests with taro, the aerated plat was given a deep plowing on June 10, 1913, while the nonaerated plat was plowed on September 10, 1913. Both plats were planted with white taro September 14, 1913, and harvested after a period of 14 months. The results of this test showed a slight increase in the yield of taro and a reduction in the percentage of diseased corms which may be attributed to soil aeration.

These tests are but preliminary work on soil aeration. As the land has been found to be quite unsuitable for definite results, these tests, which were conducted in Nuuanu Valley, have now been transferred to a plat in Waiau, which has been known to be under cultivation of aquatic crops, rice and taro, for 25 years.

Some depression exists among the local rice growers owing to the fact that island-grown rice can hardly compete with the Texas-grown product. At this time many rice growers are hesitating in regard to the further planting of their lands to rice, the inclination being to plant partially to forage crops for maintenance of cattle and hogs. The need of a good system of rotation for this particular type of soil is manifest, and the problem will probably be solved with the cooperation of the more intelligent rice planters.

POTATOES.

Experiments with potatoes included variety, fertilizer, and spraying tests, but the exceedingly dry and hot weather conditions materially affected the results.

In a fertilizer and spraying test with Early Rose potatoes, involving 10 plats of one-twentieth of an acre each, only the 6 lower plats produced plants, the 4 upper plats receiving too small a share of the prevailing light rains to start the eyes properly. This observation was substantiated by actual moisture-content tests taken at a depth of 6 inches in the soils of the upper and lower plats. The soil of the upper plats showed 16 per cent water, while that of the lower plats showed 24 per cent.

The test of spraying with Bordeaux mixture and lime sulphur on Early Rose potatoes resulted in yields of 15 bushels for the check, 25.9 bushels for lime-sulphur spray, and 30.2 bushels per acre for the Bordeaux mixture.

LEGUMES.

Among the new legumes received for trial are three red clovers from Switzerland, Ladino, white clover, and white sweet clover (*Melilotus alba*). These were planted among other legumes on February 18,

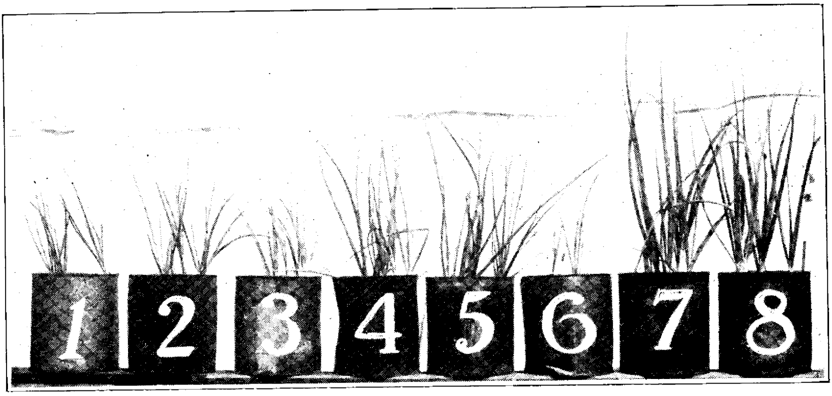

FIG. 1.—ONIONS.

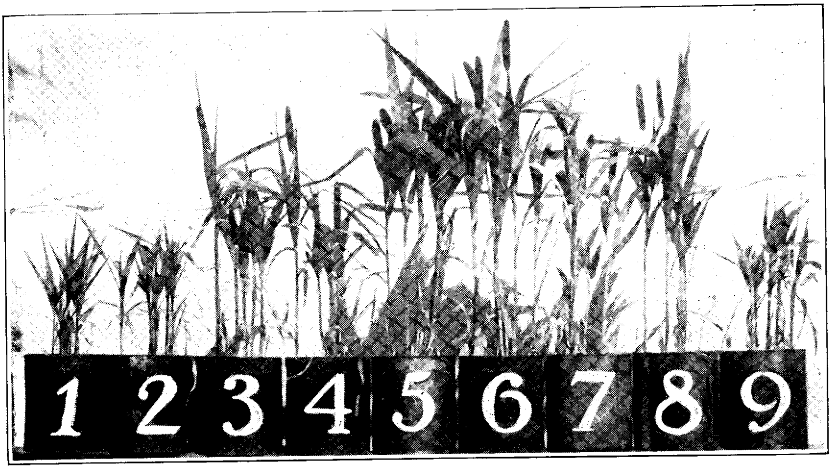

FIG. 2.—MILLET.

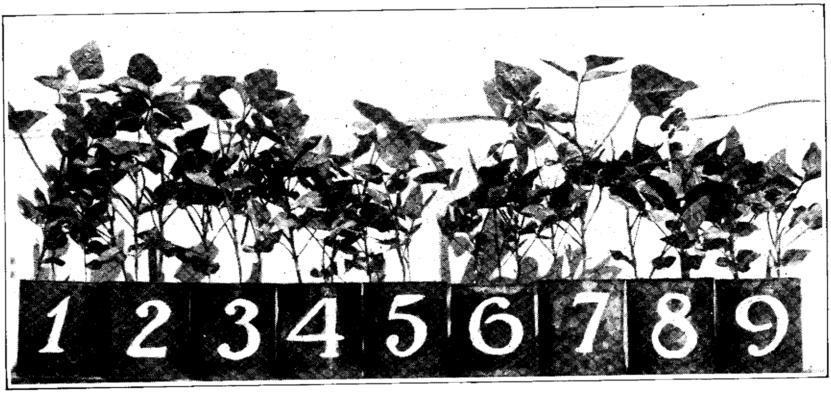

FIG. 3.—COWPEAS.

1, Check; 2, exposed to sunlight; 3, heated at 80° C.; 4, heated at 110° C.; 5, heated at 165° C.; 6, heated in autoclave; 7, treated with carbon bisulphid; 8, treated with chloroform; 9, treated with toluene.

EFFECT OF PARTIAL STERILIZATION OF SANDY SOIL ON PLANT GROWTH.

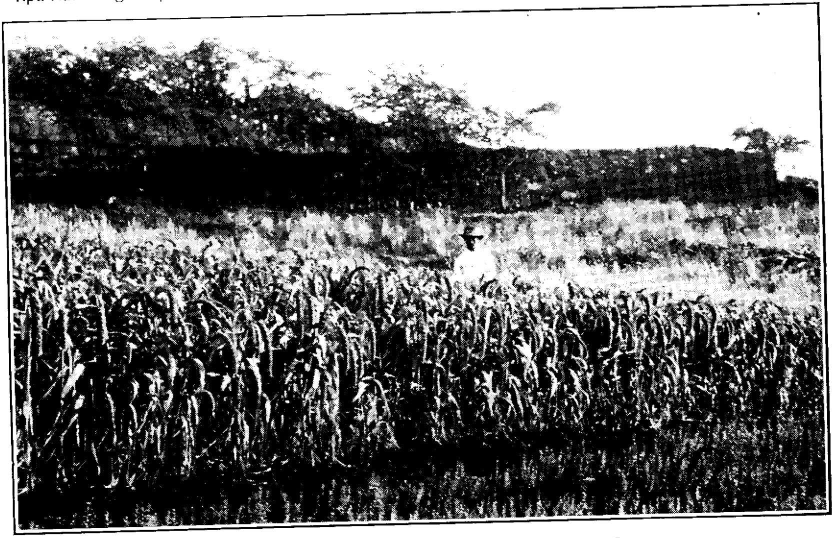

FIG. 1.—PLAT OF JAPANESE MILLET ON STATION GROUNDS.

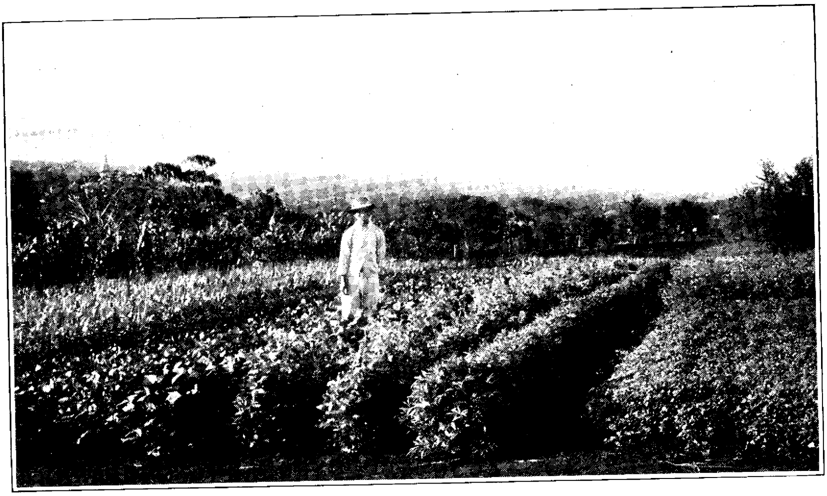

FIG. 2.—PARTIAL VIEW OF SEED PRODUCTION TESTS OF LEGUMES VALUABLE FOR GREEN MANURE.

the three red clovers from Switzerland sending out their first blooms during the third week of June, when only a little over a foot in height. All the true clovers (*Trifolium* spp.) are recommended only for high, moist localities. The white sweet clover is very similar to alfalfa, though inclined to bloom considerably later.

Crotalaria mesopontica, introduced here in April, 1914, made a slow growth until fall, attaining a height of 2 feet during the winter months, in which period the plants produced profuse blooms and pods. Another species of Crotalaria (*C. madurensis*) from Ceylon, planted April 15, 1914, had already made considerable growth by July 1. Like the other Crotalarias, this Ceylon variety is likely to earn a place among green-manuring crops for Hawaii. The two wild species of Crotalaria (*C. incana* and *C. striata*) have been planted in green-manuring tests, but fail to respond well to cultivation, the seed not germinating with the first rains, but beginning to appear some weeks later when the soil has become well settled.

In a series of sewings made with jack beans and species of velvet beans, seeds which were sown in early September made the most prolific yields of both green matter and seed. The jack bean, Yokohama bean (*Stizolobium hassjoo*), ashy pod bean (*S. cinereum*), and *S. capitatum*, matured in the middle of January. The Florida velvet bean and Mauritius bean matured one month later.

In a test for yields in forage of alfalfa under natural conditions of rainfall a Spanish alfalfa from Teneriffe and a Utah and Kansas strain of common alfalfa outyielded Peruvian and Turkestan. Given in the order of their merit, the yields in pounds of green forage per annum are: Spanish, 56,362; Kansas common, 52,065; Utah common, 45,245; Peruvian, 35,530; and Turkestan, 30,595.

Semipalatinsk alfalfa or Sholteek (*Medicago falcata*) failed to make a showing equal to that of the ordinary alfalfas or of Japan clover (*Lespedeza striata*).

SMALL GRAINS.

Further experiments with wheat, oats, rye, and barley show but small yields of grain under conditions similar to those on the station grounds. The season required from time of sowing to maturity is 5 to 6 months in duration; therefore the growth is too likely to be interrupted by long periods of drought for successful crops other than those for pasturing or green-manure purposes.

SORGHUMS.

The results of an experiment with a sweet sorghum, a non-saccharin sorghum, and Japanese cane for yields of forage over a period of 453 days were given in the last annual report. The total yields per acre (green weight) for a period of 26½ months for the sorghum and 27 months for the Japanese cane are: Sweet sorghum, 8 cuttings, 86.55 tons; nonsaccharin sorghum, 6 cuttings, 88.45 tons; and Japanese cane, 3 cuttings, 157.64 tons.

Two other sorghums, African No. 307 (S. P. I. No. 25341) and a durra, No. 760 (S. P. I. No. 27878), have given splendid yields of forage, averaging 15 tons per acre per cutting at periods of 90 to 100 days. Of the sorghums under test for forage yields, Sugar Drip, milo maize, and feterita have shown a tendency to head out too early, or at least before putting out a large amount of leaf surface, the plants appearing weak and spindling. Kafir corn, while stronger growing than either milo maize or feterita, does not seem to show the drought resistance of Sugar Drip, Amber Cane, and the nonsaccharin, long-season African sorghums. Recent observations by the writer have brought to light an inclination among farmers to send to mainland seed firms for sorghum seed without specifying the type of sorghum wanted to supply their particular needs. The seed firms naturally fill such orders with their poorest sellers, usually a kafir or milo maize, which often fail, even with irrigation, to supply profitable yields of forage.

GRASSES.

Of the several forage grasses under trial, Sudan grass still maintains the lead which it gained soon after its introduction into this Territory by its prolific yields of succulent forage. In various tests this grass has yielded from 10 to 40 tons of green forage per cutting, still heavier yields resulting from ideal conditions of soil and rainfall being recorded. Tunis grass has proved valuable as a forage grass at high elevations. In comparison with Sudan at a low elevation, Tunis grass yielded an average of a little less than 4 tons per cutting per acre for six cuttings, while Sudan yielded an average of 14½ tons per cutting per acre for seven cuttings.

Molasses grass (*Melinis minutiflora*) has gained considerable favor in the Hamakua district of Hawaii. The farmers of that district prefer the molasses grass to either Australian water grass or Para grass.

Wilder grass (*Andropogon* spp.), introduced into the Territory by Mr. G. P. Wilder in 1913, has produced excellent results where sown for pasturage. This grass is very slow in its early growth, the first blooms appearing about 120 days after germination. If used as a forage crop, Wilder grass should be cut immediately upon the appearance of the first flowering heads, because the long awns on the flowering glumes interfere with its use as forage. The station plat, planted with roots received from Mr. A. F. Judd in December, 1913, was cut for seed in June and October, 1914, and in January, 1915, and on being cut for forage May 29, 1915, this plat yielded 11.25 tons of green forage per acre.

Australian blue grass (*Andropogon sericeus*) is another valuable pasture grass for the lowlands. Its habit of growth is very much the same as that of Wilder grass, but it is a little more erect and somewhat less leafy at the bottom. Two cuttings of this grass averaged 9.5 tons green fodder per cutting per acre.

Giant Bermuda grass has met with most requirements of the average ranger for both pasturage and forage. It is adapted to all elevations up to 4,000 feet. Cuttings of this grass set out in soft, moist soil make little headway until the soil has become thoroughly compact. When once started, its growth is persistent.

Teff, Mitchell grass, wallaby grass, side oat grama, Judd, and American buffalo grass (*Bulbilis dactyloides*) have continued to persist under unusual conditions of drought for nearly two years.

BUCKWHEAT.

Further tests with Japanese buckwheat and Silverhull buckwheat were carried out in Nuuanu Valley, where greater moisture and apparently cooler conditions resulted in heavier yields of buckwheat than were obtained in any trial on the station grounds. The Japanese buckwheat matures a week earlier than the Silverhull and yields about 25 per cent more grain.

JAPANESE MILLET.

Trials with Japanese millet, undertaken at various periods, resulted in very good yields of forage when cut green, and of roughage and seed when allowed to mature. (See Pl. IV, fig. 1.) If grown for soiling purposes, millet must be cut when the flowering heads first appear, which is usually about 60 days from planting. Millet matures in 80 to 100 days under ordinary conditions, and its best period for cutting for forage value is limited to 8 or 10 days. Yields of 12 tons of forage per acre when cut green, and 3 tons roughage and 30 bushels of seed per acre when left to mature, are the approximate yields of the station plantings. As a soiling crop, millet is planted to best advantage in November and December, and harvested in January and February, the cool-weather months when sorghum yields are low.

NUT GRASS CONTROL.

The best results in controlling the spread of Japanese nut grass have been accomplished so far by spraying with arsenite of soda. Advantage is gained by spraying when the nut grass is heading out, thus killing the growth above the surface of the soil and causing the stem below the surface to rot. Spraying in single applications, however, will not kill the underground bulbs, and new shoots will again appear after a week or 10 days. Following each application of arsenite of soda, all dead growth is burned off as soon as it is sufficiently dry, thus leaving the ground bare of growth. The new shoots of nut grass are then more easily accessible to the spray. Persistent spraying at the proper time to prevent seeding may eventually sap the vitality of the underground bulbs, finally killing them.

Other methods of eradication under trial are cutting frequently at the surface and plowing with a disk plow. The results of these methods at this time are not conclusive.

COTTON.

That paying crops of Caravonica "wool" cotton can be grown in the Kona district in spite of the pink bollworm (*Gelechia gossypiella*) is indicated in the continual demand for cotton seed from the homesteaders of that district to extend their cotton fields.

Of the stand of Caravonica "wool" cotton planted on the station grounds in February, 1910, two rows have been retained to furnish data on longevity and yields. The average yield per tree per annum, when grown for four years, has been approximately 1 pound of lint. The rows are 10 feet apart, with the trees 10 feet apart in the row.

Small stands of Sea Island, Egyptian Yuma, and Upland cotton are maintained annually to supply selected seed for distribution.

SEED DISTRIBUTION.

There has been a demand chiefly for soiling and pasture and pasture crop seed, Sudan, Wilder, Australian blue, teff, Tunis, and Mitchell grass seed, while roots or cuttings of Giant Bermuda and some other grasses have been eagerly sought. In the distribution of all seed particular pains have been taken to supply the homesteader with seed of crops particularly suited to his needs and environment. No attempt has been made to supply seed of field or sweet corn other than for trial plantings. A number of the more promising legumes are being grown for seed for limited distribution to farmers for cooperation tests. (See Pl. IV, fig. 2.)

REPORT OF THE EXTENSION DIVISION.

By F. G. Krauss.

INAUGURATION OF THE WORK.

The present agricultural extension work of the station was definitely inaugurated in November, 1914, when the present superintendent was appointed to take charge of the work. This work was provided for by a special fund of $5,000 added to the regular appropriation for the Hawaii Agricultural Experiment Station. Previous to this, the extension work of the station was confined largely to projects provided for by local appropriations by the Territorial legislature. Most of the substations which were of nonexperimental character were provided for in this way. It is hoped eventually to correlate all extension and demonstration work under one head.

Hawaii is peculiar in that it has no established diversified agriculture with its usually associated groups of small independent land holdings so familiar on the mainland. Many efforts have been made to homestead various tracts of the public lands of the Territory, but no examples of markedly successful small farm communities are existent. The reason has been twofold: The establishment of communities of farmers in sufficient numbers to insure their stability can not be hoped for until it has been demonstrated by actual test that a variety of crops other than the few main staples now grown can be produced economically on a commercial scale, and that, various crops having been so grown, a profitable market can be developed for their disposal.

The lack of organized effort is doubtless the chief reason why greater success has not been obtained in the past. The Hawaii Experiment Station, and through it a few scattered farmers, have demonstrated that a large variety of crops now imported from the mainland, as well as many of those peculiar to the Tropics, can be successfully grown throughout the islands. The newly created marketing division has proved that most of such products find a ready sale, either locally or on the mainland, if delivered regularly in good marketable condition and sufficient quantity. It is the object of the new agricultural extension division to correlate these facts and to make known these and various other facilities of the United States Department of Agriculture for the direct benefit of the farmers of

Hawaii. The success that will accrue from this movement will be measured in large part by the extent to which the farmer will cooperate with the extension division.

The establishment of the Glenwood and the Hilo substations on Hawaii, the Nahiku substation on Maui, the Waipio substation on Oahu, and the Homestead substation on Kauai, together with the marketing division in Honolulu, constituted the initial cooperative effort made to aid the farmer in realizing a more normal and profitable agriculture. The establishment of a demonstration farm in the midst of the Kuiaha-Pauwela homestead tract, near Haiku, on the Island of Maui, is the direct outgrowth of an organized effort of the homesteaders to obtain this Government cooperation for which the extension division was created. It may be said to have been born of economic necessity. A group of some forty American families have cast their lot in an agricultural venture which promised well because of its favorable location and the apparent assurance of a safe and profitable crop. The successful culture of pineapples had already been demonstrated. A flourishing canning establishment was running to full capacity, and what appeared to be satisfactory contracts were entered into by the homesteaders for the disposal of their fruit. The unprecedented rains of 1914 proved disastrous to a large part of the crop, and the slump in prices (due to the troubled conditions in Europe, together with the general overproduction from new acreages) brought home in a striking manner the uncertainties of a single-crop system. The older pineapple growers had already found that successive plantings of pineapples on the same ground invariably give declining yields, regardless of fertilization and any reasonable period of fallow thus far practiced. The demonstration farm at Haiku, Maui, has under way as one of its most important projects the working out of a cropping system, which shall consist of a rotation of crops that will be beneficial to the land and of immediate cash value as well. Fortunately three or four out of the many leguminous crops already tested out on a field scale are promising for use in rotation with pineapples, which crop, it is generally believed, will remain a staple in the locality in question.

MISCELLANEOUS DEMONSTRATIONS.

Next in importance to the work of general organization of the newly created extension division is the practical farm demonstration and cooperative marketing work recently inaugurated on the island of Maui, which is to be extended as rapidly as possible to all the islands of the group.

The principal farm demonstration work on Maui is being centered on two homestead units in the Kuiaha-Pauwela tract near Haiku. The main work in cooperative marketing which has been carried on in the Kula district is also being centralized at Haiku. The work has recently been broadened to include the whole of Maui, and the other islands of the group will be given attention as rapidly as the limited means at hand will permit.

In addition to the experimental and demonstration work being carried on at the demonstration farms in the Kuiaha-Pauwela homestead tract, four extensive cooperative experiments and demonstrations and a number of minor trials are now under way on the island of Maui. A number of additional projects have been planned for the coming fall months, chiefly in the Haiku and Kula districts of Maui.

At Kula a farmers' cooperative marketing association, with a membership of over 100, has been organized and considerable farm produce marketed through it.

On both the farming and marketing phases of the extension work, as well as on the educational side, many difficult and complex problems are offered for solution. It will be especially difficult here, as elsewhere, to organize the farmers for cooperative action. The average farmer of the islands is not a business man and has not yet learned the economy and efficiency to be derived from cooperating with his neighbors. The more popular publications of the United States Department of Agriculture have been given a wide circulation among the farmers of the Territory.

One of the most important undertakings that has been imposed upon the extension division is the working out, into practical demonstrations, of efficient cropping systems whereby the fertility of the lands now being devoted to pineapple growing may at least be maintained if not improved. A permanent agriculture can not be built up under the present systems of crop and soil management as practiced even by the most advanced pineapple growers. The customary successive plantings of pineapples on the same land have invariably produced diminishing yields, even when the land has been left to lie fallow for a number of years between plantings. While a few desultory attempts have been made at green manuring pineapple lands, no systematic experiments in practical crop rotations and green manuring have been recorded. There appears to be no valid reason why the well-established principles of soil management, as they apply to other crops, should not be applicable to pineapple culture. It will be the aim of the extension division to make practical applications of many of the improved methods worked out by the

Hawaii Experiment Station, which, because of lack of practical demonstration, have not been brought home to the farmers with sufficient force to induce their adoption.

Real extension work in agriculture can not long ignore agricultural education. Such education and training has only as yet been hinted at in Hawaii, while on the mainland this important phase of extension work is receiving most careful study. The majority of rural inhabitants can not attend agricultural high schools and colleges. For these the best possible educational advantages should be brought to the farms and homes.

DEMONSTRATION FARMS.

The main farm demonstration work on Maui is being centralized on two homestead units situated in the Kuiaha-Pauwela tract near Haiku. The two farms are representative of average conditions in the lower and middle section of the homestead tract and apparently of a large part of Maui.

The lower homestead is in the drier section of the Makawao region. The average rainfall is about 40 inches per annum. Climatically this section appears to be well adapted to diversified and intensive agriculture. This particular homestead was among the first to be settled upon, the original settler planting his first crop of pineapples in 1911. An excellent crop of fruit was harvested in 1913, but in the succeeding year many of the plants sickened, and the yield of fruit was greatly reduced in consequence. Owing to financial difficulties, the original settler abandoned the farm in the fall of 1914. It was taken over by the superintendent of extension for demonstration purposes in January, 1915. The crop for 1915, both from old and new plantings, was practically negligible. In the sheltered portions of the farm fine vegetables in considerable quantity were grown. Both bananas and papayas, though now growing without care, are of excellent quality. The pineapple fields, consisting of about 10 acres, were abandoned to weeds, as it was considered hopeless to restore them to profitable production. However, about 50 tons of pineapples weighing a little under 3 pounds each was produced.

Immediately upon taking possession of the lower homestead, a tract of 16 acres was cleared of brush, the main growth being heavy grass sod and young guava which had sprung up after 1½ years of abandonment. The land was then given 3 plowings, 6 disk harrowings, and 2 draggings at a cost of $40 per acre for the tillage operations. This cost is on a basis of $6 per day for a man, 3 good working mules, and implements. The first crops were planted on May 6 and the last on May 28, 1915. The following crops have been planted for demonstration purposes.

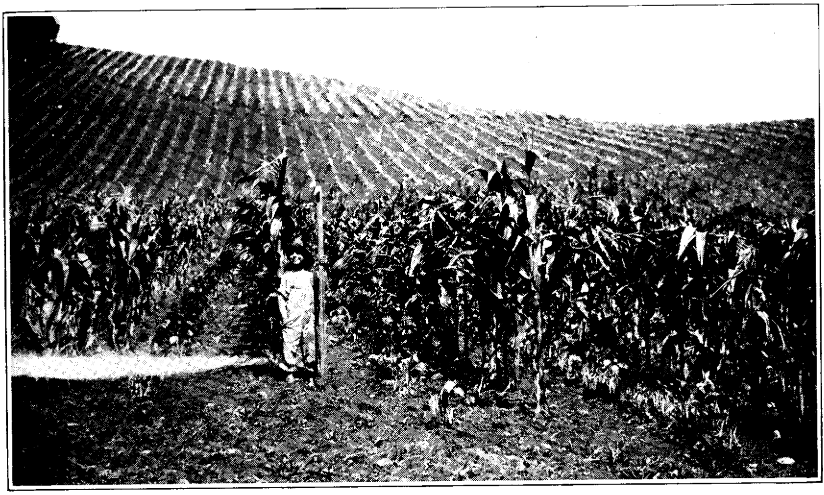

FIG. 1.—BEANS AND CORN INTERCROPPED, PINEAPPLES IN BACKGROUND, HAIKU DEMONSTRATION FARM.

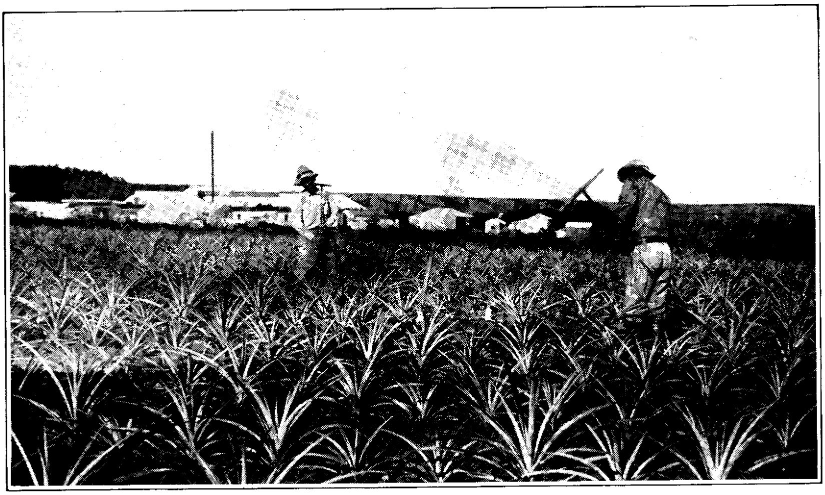

FIG. 2.—PREPARING GROUND IN PINEAPPLE FIELD FOR DYNAMITING, HAIKU DEMONSTRATION FARM.

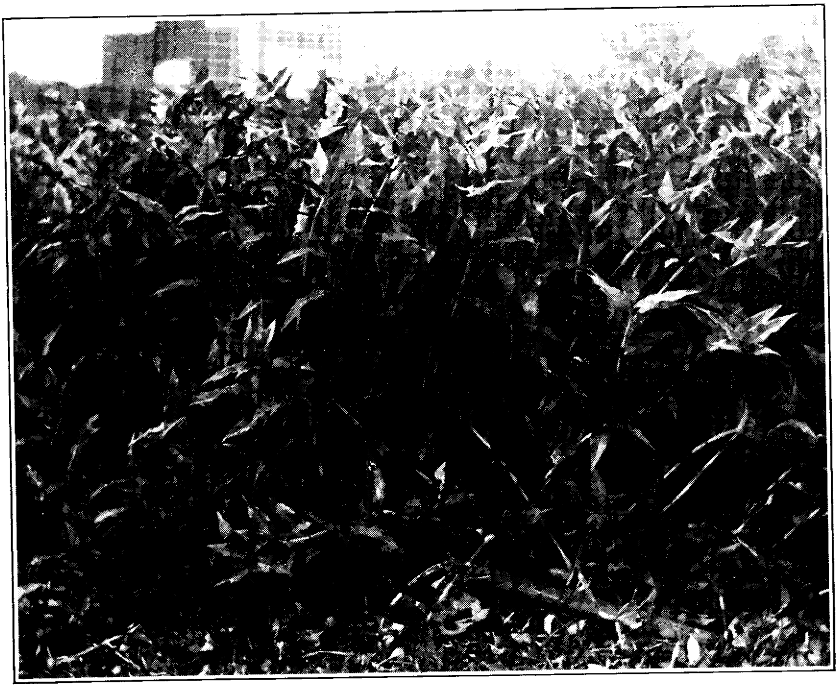

FIG. 1.—DETAILED VIEW OF HONOHONO, A VALUABLE SOILING CROP FOR DAIRY CATTLE, GLENWOOD SUBSTATION.

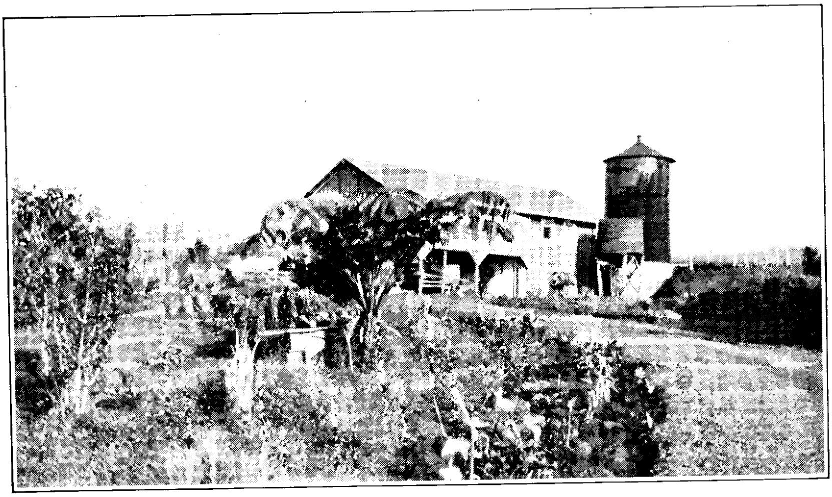

FIG. 2.—SILO AND GENERAL VIEW OF THE GROUNDS OF THE GLENWOOD SUBSTATION.

Crops grown on the lower demonstration farm.

Crops.	Number of varieties.	Method of culture.
Field corn and beans	4 each.	Intercropped.
Jack beans for seed	1	In rows 2½ and 5 feet apart.
Sunn hemp	1	In rows 2½ feet apart, 25 and 50 pounds seed per acre.
Soy beans	4	Inoculated and not inoculated.
Pineapples	1	Ordinary.
Do	1	To be plowed under and green manured.
Para grass	1	Broadcast.

The middle demonstration farm is a well-established homestead. The equipment in farm buildings, farm machinery, implements, work animals, etc., is among the best in the Kuiaha-Pauwela and Kuiaha-Kaupakuhua homestead tracts which surround it. Systematic plantings have been made each year since the homestead was settled in May, 1912. While the main crop has been pineapples, for which the lands are especially well adapted, a cropping scheme is in operation which includes a definite rotation system. The crops employed are shown in the following table:

Crops grown on the middle demonstration farm.

Crops.	Number of varieties.	Crops.	Number of varieties.
Pineapples, 1, 2, and 3 years old	1	Peanuts	4
Corn	2	Watermelon	4
Legumes	4	Artichokes	1
Potatoes	8	Field beans	2
Sweet potatoes	3	Forage grass	2

The young pineapple plantings are being subjected to intercroppings of dwarf field beans, as are also some of the plantings of corn. (See Pl. V, fig. 1.) The success of this demonstration has introduced the practice among a number of local pineapple growers. A series of fertilizer, tillage, and dynamiting experiments with pineapples is also under way. (See Pl. V, fig. 2.) All crops grown are under fertilizer, liming, and tillage experiments. Careful records are being kept of all farm operations, and it is expected that these data will prove valuable to prospective homesteaders.

COOPERATIVE EXPERIMENTS.

In April, 1915, a 6-acre, cooperative, green-manuring, and legume-rotation experiment with pineapples was entered into with the Haiku Fruit & Packing Co. A project was worked out whereby the influence of green manuring and rotation over a period of five years can be determined. Four leguminous crops are under test. The company furnishes the land, labor, and seed, while the extension division gives general supervision when such becomes necessary. The work is being unusually well done by the company and valuable results are expected.

A private planter has requested the services of the extension division in carrying on cooperative experiments in dynamiting and in treating soils antiseptically in pineapple culture, the land, labor, and materials all being supplied by the owner, who is one of the most advanced planters in the district. Another pineapple planter, who is entering into the dairy business, is undertaking a cooperative forage-crop and pasture-grass experiment. Largely through the suggestion of the extension division, this same farmer has acquired a herd of pure-bred Jersey cattle.

Early in the spring, through the advice of the extension division, an acre of beans was planted by each of some 20 homesteaders and others. The crops from all these tracts have been harvested and nearly all have been thrashed and marketed. It is hoped that bean culture may in time become as important an industry in this region as it already is in Kula.

Fifty pounds of Sudan grass has been distributed in the district, mostly in 1 and 2 pound lots, for trial and report. One grower reports that but for his half-acre patch of Sudan grass he would have suffered materially for forage for his dairy herd.

Four different projects have been planned and three are under way for cooperative leguminous crop demonstrations. These will be located along the main road running through the Kuiaha-Pauwela homestead tract. The value of these legumes has already been demonstrated on the extension division farms. The most promising kinds are jack beans, velvet beans, sunn hemp, and cowpeas. These are valuable for green manuring and forage, as well as for their seed which is now beginning to be eagerly sought by the sugar plantations.

The cooperation of the Territorial office of public lands and the division of forestry has been secured, and it is hoped that newly opened homestead tracts throughout the islands may hereafter have at the outset whatever assistance the extension division may have to offer.

In the newly surveyed Makawao homestead, which is shortly to be opened for settlement, a homestead unit is to be set aside for agricultural demonstration under the supervision of the extension division. It is also planned to reserve wide tree belts as a protection against the excessive winds that prevail there. Mr. C. S. Judd, chief forester of the Territory, is to give this matter his personal attention.

REPORT OF THE GLENWOOD SUBSTATION.

By F. A. Clowes.

During the year the work of the substation has been continued along lines similar to those indicated in previous reports. The most interesting features of the crop work are the use and value of honohono for a soiling crop, *Paspalum dilatatum* for pasture, and cane tops for silage. Excellent results have been secured with chicks kept according to approved methods, and a flock of 250 pullets has been raised and housed in colony houses designed from standard plans, but altered slightly to suit local conditions. Considerable extension work has been carried on with excellent results.

HONOHONO (*Commelina nudiflora*).

From May 1, 1914, till April 30, 1915, the yield of honohono from a plat 10 feet square, which was a representative part of the field, was weighed at each cutting. The total yield of green feed per acre, calculated from this plat, was 223.6 tons (Pl. VI, fig. 1).

Honohono is an extremely succulent feed, much relished by cattle. Cattle fatten and produce an abundance of milk when pastured where it is plentiful. A study of the records of one of the pioneer dairymen at Glenwood shows that during a 29-month period, at a time when honohono was abundant, his herd of 33 cows of mixed breed gave an average annual milk flow of 6,100 pounds of milk per cow. The highest 12-month record was 8,616 pounds, and the lowest was 3,092 pounds. One dairyman in the same region secured a yield of 11,000 pounds from a Holstein cow fed honohono. It is believed that the yield of green feed recorded at the substation is not exceptional. Calculated from analyses reported by the station,[1] a ton of green alfalfa would contain the same amount of protein as 4.7 tons of honohono. Looked at in another way, 223.6 tons of honohono, the yield of 1 acre, would contain the same amount of protein as 47.6 tons of green alfalfa, which would be considered an exceptional yield from an acre in one year. For the food constituents other than protein, the comparison is even more favorable to honohono. To cultivate honohono, an abundant supply of manure is necessary. This would be readily available were adequate provision made for the stabling of the cattle, as suggested elsewhere in this report. The cultivation of honohono as a soiling crop is proving very satisfactory in this region.

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[1] Hawaii Sta. Bul. 13 (1906).

PASPALUM DILATATUM AS A PASTURE GRASS.

As a pasture grass, *Paspalum dilatatum* has given excellent results. Its strong deep root system enables it to withstand the tramping of stock in wet weather better than any other grass tested at Glenwood that is equally relished by the cattle. It has been extensively planted by local dairymen since its introduction by the substation. Both seed and divided roots have been used for planting. Homesteaders have been supplied liberally with roots from the fields of the substation.

CANE-TOP SILAGE.

The silo (see Pl. VI, fig. 2) was filled during June and July, 1914, with cane tops from neighboring fields. The weather during these months was excessively wet. The roof was not put on the silo till filling was almost completed, and as a consequence, much water found its way into the silo. The cane tops were bundled in the field and loaded on cane cars on the portable track used by the Olaa Sugar Co. in getting out the cane. The cars when loaded were hauled to a convenient place, and the tops were transferred to a wagon and hauled to the silo. Owing to various unavoidable interruptions, the silo filling was greatly delayed, and the silage was expensive. Some of the cane tops were cut two weeks before they were put into the silo. Notwithstanding the resulting staleness and the excessive amounts of water that went into the silo during filling, the silage was of fair quality and was eaten readily by the cattle and horses. To adapt the silo to profitable use for cane tops, it should be so located that there will be a minimum amount of labor in getting the cane tops into the silo. Since the economical use of the manure is a factor of controlling importance in any scheme for the use of considerable quantities of cane tops, the location of the silo and the feeding yard should be such that the manure can be supplied to the fields without too long a haul. The yield of cane tops per acre is about 10 per cent of the weight of the usable cane. On the unirrigated plantations this by-produce would run from 4 to 8 tons of cane tops per acre. These amounts are equivalent to about half the yield of corn silage secured by the live-stock farmers. A comparison of analyses of corn silage and cane-top silage indicates that the cane-top silage and corn silage are probably not greatly dissimilar in feeding value. This being so, it only remains to develop satisfactory practical methods to produce, on every acre of cane land, a crop of beef, milk, or butter as a by-product of the sugar industry. This would ordinarily be equal to one-half of the main crop of the live-stock farmer elsewhere. In the feeding of silage to secure economical returns, supplementary grain feeding appears to be necessary. With judicious care of the manure, the fertilizing elements secured through the use of these grain feeds would replace much of the commercial fertilizer at present imported.

CATTLE.

During the year the station loaned the herd bull, Raymond of Alta Vista, to the Board of Commissioners of Agriculture and Forestry for four months, and he was placed by them at the Hilo Quarantine Station, where 15 cows were brought to him for service. This arrangement distributed his service over a large area without inconveniencing the Glenwood homesteaders to any extent.

The herd now consists of 1 registered Guernsey bull and 3 registered Guernsey cows, 1 registered yearling heifer, 2 registered heifer calves, and 2 unregistered Jersey cows. To adequately demonstrate the best methods of caring for cattle, the herd should be increased to 10 or 15 milking cows. Funds are not at present available for this purpose.

In the earlier part of the year, just previous to calving, one of the Guernsey cows, Kitchener's Vimera, was much troubled with sore feet, which, with the exposure to the heavy rains and the strain incident to parturition, kept her in very poor condition for several months. During wet seasons like the summer of 1914, the feet of cattle at pasture develop raw sores in the flesh between the divisions of the hoof. The horn on the inner surface of the hoof also becomes pitted and decayed, and the toes become sore. The horn of the hoof sometimes becomes much elongated, commonly reaching a foot in length unless trimmed. This lengthening is due to the absence of hard ground, which would ordinarily wear off the natural growth of hoof. The weight is then thrown back upon the rear of the hoof, thus adding to the other discomforts. Unless given attention, cows become so lame that they are unable to graze over a sufficient area while at pasture to keep them in good condition. By trimming off the surplus horn, by washing between the claws and applying antiseptics, and by keeping the animals out of the mud, cures are easily effected. Three of the cattle at the substation developed these troubles in the earlier part of the year before an extension of the stable made it possible to shelter all the stock.

When any considerable number of animals is affected their care becomes a serious burden unless adequate stabling is available to permit of the animals resting on dry ground during heavy rains and at feeding times. The heavy rains, even when they do not cause sore feet, affect adversely the condition of the cattle, no matter how much they are fed, unless they can have adequate protection. On account of these facts outlay for stables and covered yards can be made a profitable investment. The value of the manure saved by providing concrete floors in these shelters would eventually repay the cost of the concrete construction. In July the station stable was extended to provide cover for all the stock.

FARMING OPERATIONS.

Throughout the whole region on the windward side of Hawaii and Maui the weather was so wet from the first of April to the end of September, 1914, that field work, with the exception of the unavoidable cane harvesting, was at a standstill. At the end of September, when the weather was comparatively clear and cultivation was possible, the fields were quickly restored to good condition, and little injury resulted to growing crops. In the cane fields effective results were obtained in weed control by the use of arsenite of soda on the dense growth. This destroyed at one spraying stands of weeds that would have taken several cultivations to subdue. At the substation no advantage could be taken of the good planting weather in the fall, since funds for the pay of labor were not available on account of the curtailment of the Territorial allotments. On this account no plantings were made from April, 1914, until April, 1915. Seasons such as that of 1914 occur only occasionally and do not prevent farming operations where the operators are not hampered by adverse circumstances other than the weather. Their occurrence does, however, point to the necessity of placing chief reliance on perennial crops such as the pasture grasses, Para grass, honohono, sugar cane, sorghum, and others that will undoubtedly come into favor with the greater use of cultivated crops in connection with the live-stock industry.

POULTRY.

The greatest drawback to poultry culture in Hawaii is the prevalence of a number of contagious diseases. Probably the most troublesome of these is sorehead.[1] It is very destructive to young chicks, but not to mature fowls. The method by which this disease is carried from fowl to fowl is not definitely known. Mosquitoes and insect parasites probably play an important part. The disease is most prevalent during the warm months from May to September. It has been the experience of many that early hatched chicks either escape the disease altogether or recover from the attack. Incubator-hatched chicks, brooded artificially and kept from contact with other fowls, are less frequently affected than chickens brooded under hens. Chicks kept off the wet ground and properly cared for under cover till 6 or 8 weeks old are less frequently affected than those allowed on the ground at an earlier age. Well-fed chicks, given abundant exercise, are likewise less frequently troubled than neglected chicks.

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[1] Hawaii Sta. Press Bul. 46 (1914).

There has been no contagious sickness among the birds at the substation. This is attributed to the fact that care has been taken to prevent contact with other birds. The houses are disinfected regularly, and the chicks are hatched early in the season. At the close of the breeding season in 1914 and before any of the chicks were put out of the chick pens, the breeding flock was disposed of, and the chicken houses were thoroughly cleaned and disinfected before placing the chicks in them. With the exception of three male birds, purchased for breeding purposes, the entire flock has been hatched in incubators and raised on the place, free from contact with other fowls. The roosts and dropping boards have been sprayed bimonthly with a mixture of 4 parts crude oil, 2 parts kerosene, and 1 part creolin. The houses are thoroughly cleaned annually and sprayed inside and out with the above mixture. As a result the birds have not been troubled with lice and mites, which in large measure explains the absence of disease. At the commencement of the fiscal year there were in the station flock 38 White Leghorn pullets and 12 Rhode Island Red pullets. One Rhode Island Red pullet was killed for examination. She was apparently healthy and fat but laid no eggs, although she entered the trap nest regularly. A post-morten examination showed that the abdominal cavity was filled with soft-shelled eggs, flattened out, and occupying all the space not filled with the intestines and other abdominal organs.

Throughout the year the flock was fed on commercial scratch feed scattered in the litter during the day and in a hopper just before night. The total consumption by the flock for the 12 months was 1,800 pounds, which cost $45, or 36 pounds per bird at a cost of 90 cents per bird. As the birds had free range, they picked up a large part of their living. During the year 4,204 eggs were produced. Part of the feed cost should be correctly chargeable to increase in the weight of the birds, but charging it all to the eggs, the cost per egg for the grain feed was 1.07 cents. The average wholesale price of eggs in Honolulu was about 43.5 cents per dozen, from which must be deducted the freight and marketing charges of about 5 cents per dozen.

Colony houses of four designs have been erected to determine their relative suitability. The design that seems most satisfactory is of the shed-roofed type, 10 feet square, built of surfaced, tongued, and grooved northwest fir, with ceiling over the roosts for ventilation, built-in dry mash hopper, roosts for 50 birds, and 15 trap nests. The cost of each house was $60. Allowing for 5 per cent depreciation and 5 per cent interest on the investment, the cost of housing per bird would be 12 cents per year.

EXTENSION WORK.

Through the month of July the superintendent of the substation was instructor in agriculture at the summer school for teachers under the auspices of the department of public instruction.

Through the suggestion of the substation, the cooperation of a number of civic organizations was secured for the holding of the first Hawaii County Fair at Hilo. The superintendent of the substation was the chairman of the managing committee of this fair. Great success met the effort expended in this attempt, and the fair is assured as an annual event. It has done much already to stimulate interest in poultry culture and the breeding of better live stock. Its influence on other branches of agricultural production is also considerable.

The boys of the Glenwood School have been given weekly instruction in milk testing at the schoolhouse and later at the substation. The work is now developing along the lines of cow-testing associations. The boys range in age from 8 to 15 years. The parents of each boy are directly engaged in butter making. The boys are much interested in the work and the accuracy of their testing is surprising.

The substation cooperated with the Hilo High School in the operation of a hatchery, and aided in the agricultural work by giving suggestions and advice. The substation supplied the hatchery with 100 dozen eggs for hatching, and loaned one incubator at the close of the season's hatching at the substation. Through the Hilo High School hatchery over 3,000 pure-bred, day-old chicks have been distributed. Where it was acceptable to the purchaser, advice was given as to the care of the chicks. This advice was naturally more frequently sought by school pupils than by adults. The system of care and feeding advocated was that outlined above as in use at the substation.

In every case where this system has been followed excellent results have been secured. Two cases of sorehead epidemic occurred among the chicks that had been distributed from the High School hatchery, but in both of these cases the chicks had been kept on the ground, contrary to the advice given. Sorehead was very prevalent in the town of Hilo during the months of April, May, and June, 1915. It is noteworthy that no cases occurred among the chicks sold from the hatchery and raised under cover and otherwise cared for according to directions, including the feeding of dry mash and green feed from hoppers and scratch feed in deep litter. Poultry culture has been greatly stimulated by these efforts.

In recent years the methods of field cultivation on many of the sugar plantations have been greatly changed. At one time most of the field work was done by large gangs of coolies under the supervision of overseers. Gradually this method is being superseded in the interest of efficiency by cutting up the fields into smaller areas, which are leased to small planters.

Most of the plantations near Hilo plan to retain for cultivation by hired labor only sufficient land to profitably employ their labor force during the time the mill is not grinding. A great deal of the homesteading of the public lands has been done by citizens whose training has not been along the line of farming. Where the homesteads have not been sold shortly after being deeded to the homesteader, they are usually rented to the class of tenants that are leasing the lands of the large plantations. There has, therefore, developed a large class of tenant cane growers and a rural social problem, similar to that presented by farm tenancy elsewhere, but complicated by the one-crop system and the fact that the largest landlords, the plantation corporations, also control the cane market of the tenant.

These people, the homesteading landlords and homestead cane growers, have repeatedly appealed to the station for advice and assistance. This work did not fall directly within the scope of the station work, but such assistance has been rendered as seemed to be in accord with the general policy of the department.

HORTICULTURAL OBSERVATIONS IN PORTO RICO, CUBA, AND FLORIDA IN RELATION TO THE HORTICULTURE OF HAWAII.

By J. EDGAR HIGGINS.

In June, 1914, when the writer was about to close a year's leave of absence, instructions were received to report for duty in Porto Rico and proceed to Honolulu via Cuba and Florida, making observations of tropical horticulture en route. Considerable attention had already been given to the fruit industries of Porto Rico, and, after a week or more of further investigation, the steamer was taken, on June 29, direct to Havana. No attempt at an exhaustive study could be made, but much valuable comparative information was obtained, a part of which is recorded herewith, and much of which is on record for reference when required.

THE PINEAPPLE INDUSTRY IN PORTO RICO.

The pineaple industry of Porto Rico occupied during the year 1912 an area of 3,654 acres.[1] The output was valued at $943,445, of which $258,671 represents the value of the canned product and $684,774 the value of the fresh fruit. Thus, less than 28 per cent of the total value of the crop was received for the canned product. The canning of pineapples, however, has been on the increase steadily, but has not increased so rapidly as has the export of fresh fruit, which in 1914 was valued at $1,245,215. The proximity to great markets and comparatively frequent opportunities for shipping account for the more rapid development of the fresh-fruit industry. Steamers ply frequently between the island and New York.

The organization of the industry is quite different from that in Hawaii. There are practically no large corporations in Porto Rico. For the most part the holdings are small as compared with those of Hawaii. There are probably few, if any, individual or corporate holdings in excess of 250 acres. Pineapples are grown almost exclusively by Americans on farms or plantations. There are thus a good many growers interested in the business, but they are very widely separated, being scattered throughout the greater portion of the northern side and the western end of the island.

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[1] War Dept. [U. S.], Ann. Rpt. Governor P. R., 12 (1912), p. 135.

CULTURAL METHODS.

As has already been indicated, the pineapple plantations are located chiefly along the northern side and western end of the island. These are all at comparatively low elevations, many being only slightly above sea level and none above a few hundred feet. They are nearly all served by the railroad which extends around the western end of the island from Ponce on the south to many miles east of San Juan on the north.

The soils on which pineapples are grown in Porto Rico are of several types, the sandy and sandy loam predominating along the northern side of the island, with some gravelly loam. Some clay loam, particularly on the western end, is devoted to the industry, and it resembles in appearance much of the pineapple soil of Hawaii. Some indications of manganese are found, but manganese does not appear to have given rise to much difficulty. Drainage is as vital a problem in Porto Rico as in Hawaii. Even the sandy soils are in many cases underlaid by a more or less impervious stratum which makes drainage difficult, particularly on lands with very slight grade.

Propagation methods do not differ materially from those in Hawaii, except that crowns are seldom if ever used. Slips and suckers are used almost entirely. With these is to be included the underground sucker which in Porto Rico is called a ratoon. Perhaps the reasons for the disuse of crowns are that the Red Spanish variety, which is the one most commonly grown, produces suckers abundantly; that these suckers produce fruit much more quickly than the crowns, and, further, that the Cabezona, which is the only other variety of importance, is extremely slow in producing a crop from crowns.

In preparation of the soil a long period of tillage is found necessary, as in Hawaii. The ridge system of planting is much in use, probably because it aids in quickly removing excessive water from the plants in a country where torrential rains are common. Flat planting, however, is seen in many places. About 12,000 to 14,000 plants per acre are set in case of Red Spanish, and various forms of arrangement are employed, some plantings being made as close as 12 by 12 inches in the beds or double rows. Much of the planting is done in the winter, the season of heavy cropping coming in the spring. Some progressive planters have found it possible and advisable to plant in July and thus distribute the season of cropping over a larger portion of the year, getting perhaps 75 per cent of the crop out of season or when there are few pineapples on the market and prices are good.

Pineapples are much used as an intercrop with citrus trees, and this combination, if carefully and wisely handled, sometimes results in the pineapples practically paying for the establishment of the citrus orchard (Pl. VII, fig. 1). About two ratoon crops are generally taken whether the pineapples are grown exclusively or as an intercrop. Replanting does not usually follow immediately after the destruction of the first planting. It has been found necessary in Porto Rico, as in Hawaii, to prepare the land very thoroughly before the second planting. Where it is possible, fallowing for a year or more is frequently practiced, the land being used for pasture. In the destruction of the old plants, the ever-present machete is very much in evidence. This swordlike tool, which is used by the natives for almost every conceivable purpose in gardening, is very effective in cutting down the old plants. If the growth is dry enough after weeds have been allowed to grow it is sometimes burned over.

The cost of production of pineapples in Porto Rico is apparently about the same as in Hawaii. Pineapple lands, unplanted, cost from $75 to $250, the price being determined to a large extent by location. Labor can be secured at 62 cents per day, but because of the larger proportion of handwork and possibly lower efficiency, the planter's labor bill is probably not less in Port Rico than in Hawaii. The yield of pineapples ranges from 10 to 14 tons per acre. Fertilizers are used rather freely and with profit to the grower.

The varieties of most importance have already been mentioned. It is estimated that probably 90 per cent of the crop is Red Spanish. This variety is known to most growers in the Territory of Hawaii, although it has never proved popular here except in the Kona district of the Island of Hawaii. It is a vigorous grower and yields freely. The fruits are of small size, ranging from 1½ to 4½ pounds. They are of good quality, ship excellently, and sell well on the market. They are better adapted to fresh-fruit trade than to canning, because of their small size, which makes it impossible to get a large percentage of slices of sufficient diameter to pack the highest grade of canned fruit. They are, however, much used in canning. The Cabezona is an extremely large fruit, averaging from 8 to 10 pounds, 15 pounds being not uncommon, while fruits weighing 18 to 25 pounds have been reported. This variety has been grown in one locality in Porto Rico since the early part of the nineteenth century and has come to be known in some other parts of the world as the variety Porto Rico. Its origin in the island is not known. It seems well adapted to local conditions, particularly on the loamy soils, and is planted in those parts of the island where canning is being chiefly practiced, since it is not well adapted to the fresh-fruit trade. The Smooth Cayenne variety, upon which the Hawaiian industry is based, is almost never grown in Porto Rico. Many other varieties have been introduced, including the hybrids originated by the United

States Department of Agriculture, but up to the present time none have proved popular for commercial cultivation except the two named above.

DISEASES AND INSECTS.

The diseases of the pineapple in Porto Rico are not materially different from those of Hawaii. Soft rot, due to the fungus *Thielaviopsis paradoxa*, is more or less destructive to fruits in transit, but the Red Spanish variety shows considerable resistance, and by proper care in curing, packing, and transportation this trouble can be rendered unimportant. Base rot, due to the same fungus, is somewhat in evidence, but in the warm soils, if drainage is provided, it does not cause much loss. Leaf spot, also due to this fungus, is found chiefly in the coolest part of the year and in wet weather. Sun scald, following the bending over of the fruit, occurs as in Hawaii, but because of the small size of the fruits and the close planting, the loss is small in the Red Spanish variety. The practice has been followed to some extent of covering these exposed fruits with a little dried grass, the work being performed by children. Pineapple wilt occurs, but usually only where the conditions are unfavorable.

Perhaps the chief insect enemy of the pineapple in Porto Rico is the mealy bug (*Pseudococcus bromeliæ*) which is so common in Hawaii. It is accompanied by ants, which aid in its distribution. When the necessity arises, this insect is held in check by means of sprays. The pineapple scale (*Diaspis bromeliæ*) was not seen by the writer in Porto Rico and was said not to occur in the island.

MARKETING.

The fresh-fruit trade in pineapples from Porto Rico is exclusively with New York as a distributing center, except for a few small shipments which may go to New Orleans. The fruits are shipped in the Florida or Red Spanish crate. The dimensions of this are 10½ by 12½ inches inside measurement and 36 inches long outside. This crate is well suited to the Red Spanish variety. It contains from 70 to 75 pounds of fruit, net weight, averaging about 72 pounds. There are from 14 to 60 fruits in a crate. There are few that run so large as 14's, and very few so small as 60's are shipped. The sizes and approximate corresponding weights are indicated in the table on page 63. The prices received for the fruit of late years have averaged about $2.50 per crate for the sizes ordinarily shipped—that is, from 42's up.

Until 1910 the prices received were very much lower. Up to that time there was no thorough organization of the fresh-fruit trade.

Fruits were shipped by individuals on consignment, and the results were about as unsatisfactory as those generally brought about by this system. At that time the Porto Rico Fruit Exchange was organized, at first having a severe struggle for existence, but now being well established. This is an organization of growers. At first stock was sold to nongrowers, but at the present time a man must be a bona fide grower to secure stock. Each share bears one vote in the control of the organization, and no grower can now buy more than five shares. This organization now ships about 60 per cent of the fruit grown in Porto Rico for export. It is estimated that about 85 per cent of the growers are members of the organization, but because of the heavy shipments of a few comparatively large growers, who ship independently, less than 85 per cent of the fruit is controlled by the organization. The shipping of these larger growers, however, is organized on a business basis, so that it does not demoralize the market as is always done by a large number of small growers shipping to a distant market without organization. The exchange handles about $600,000 worth of pineapples and citrus fruits per year, which is the product of between 200 and 250 shippers. Most of these shippers represent individuals or companies. There are only one or two local exchanges. The Porto Rico Fruit Exchange employs a representative to look after the shipping of its fruit in San Juan, and a dock superintendent in its employ receives the fruit in New York, examines it, and if necessary has it repacked. An office is also maintained near the fruit auction rooms in New York City. To these auction rooms samples of each brand in the shipments are taken, and from these samples the whole shipment is sold. Steamship companies segregate all brands, sizes, etc., on the wharf where the buyer takes charge of his fruit. By this system of organized marketing the fruit growers of Porto Rico have been able to bring up the standard of their pack, to purchase in large quantities packing material and fertilizers, and to raise the price from a point that barely covered the cost of production to a standard that makes a good profit in the industry.

CANNED PINEAPPLES.

There are about half a dozen or more plants engaged in the canning of pineapples in Porto Rico (Pl. VIII, fig. 1). Those at the western end of the island are putting up the Cabezona variety, which is being grown for canning purposes. They also can the Red Spanish, but this variety is put up chiefly near San Juan. The style of pack is somewhat different from that of Hawaii. Some of the canneries make a specialty of fruit for confectioners' trade. For this purpose the pineapples are gathered before they are thoroughly ripe, and while the fruit is quite white in color. Some of it is put up without sirup. The small size of the Red Spanish, especially as the best of the fruit is likely to be shipped fresh, makes it impossible to put up a large percentage of the pack in the highest grade of sliced fruit. Many of the quite small fruits are used to put up crushed, grated, pie-grated, and other forms.

The prices which it is necessary to pay for fresh fruit are much higher than in Hawaii. The success of the fresh-fruit trade brings about this condition of affairs. The table below indicates the prices paid and the classification of the fruits.

Classification and prices paid in Porto Rico for Red Spanish pineapples for canning.

Size.	Approximate weight per fruit.	Range in price per ton.	
		1913	1914
	Pounds.		
14's	5.1	$20 to $25	$24 to $31
18's	4		
24's	3		
30's	2.4		
36's	2	10	12 to 15
42's	1.7		
48's	1.5	5	5 to 10
54's	1.3		
60's	1.2		

In some canning establishments a somewhat different method of classification has been followed, and in some instances fruits weighing less than 1.5 pounds are not accepted.

It will be seen that 30's, or fruits weighing 2.4 pounds each, are accepted as first grade, while 36's, 42's, and sometimes 48's go as second grade. Some of the canneries will accept 60's, or fruits weighing only 1.2 pounds each, at a reduced price. It will be noted that for the first grade of fruit in 1914 the prices paid were from $24 to $31 per ton. In some cases this fruit was delivered at the cannery and in other instances to the railroad, the buyer paying the freight. The second grade sold for from $12 to $15 per ton. These prices were considerably in advance of those of 1913, when first grade sold for $20 to $25 and second grade for $10. In some instances all fruit from 48's to 14's was taken in 1913 at a uniform price of $22 per ton.

It will be noted that these prices are higher than any that have been paid in the history of the canning industry in Hawaii, and they exhibit a strong upward tendency simultaneously with the complete demoralization of prices on fresh pineapples in Hawaii, where they sold as low as $5 per ton for first-grade fruit. No attempt is made here to explain this wide divergence in prices of raw material. The canned product from Porto Rico sells (at retail) at somewhat lower prices than that from Hawaii.

PINEAPPLES IN CUBA.

Cuba ships about a million and a quarter crates of pineapples per year, the size of the crate being the same as that used in Porto Rico. A striking contrast between the Porto Rican and Cuban industry lies in the fact that there are many small growers of pineapples among the Cubans themselves. The cultural methods are similar to those pursued in Porto Rico, and the soils likewise vary from sandy to loam. The Red Spanish is the predominating variety. but a few Cayenne are shipped, chiefly from the Isle of Pines. The Abachi (Abakka) is frequently found in the home markets and is popular because of its fine flavor and texture, as well as its attractive appearance. This is a conical-shaped fruit and has the striking character of ripening before the fruit has turned yellow. If kept, however, a very fine color appears before the fruit has become too ripe for use. This variety sells in the Havana market at higher prices than the Red Spanish.

Practically all the Cuban crop is shipped as fresh fruit except the portion which is so consumed at home. There is very little organization of the pineapple growers for marketing purposes, which results in low prices and demoralization of the markets. Much of the packing is also poorly done, without sufficient curing of the fruit, or care in its handling. Fruits are often brought from the field to the packing house in bulk on large bullock carts without springs (Pl. VIII, fig. 2), which, in itself, would cause enough bruises to account for the very heavy losses which are often sustained through decay in transit.

There appear to be large possibilities for the development of the pineapple industry in Cuba. The areas of available land at comparatively low prices, the proximity to the great markets of the United States, together with the location of the island with reference to the routes of travel to Europe, all are favorable to a large development. The cost of labor is higher than in Porto Rico.

PINEAPPLES IN FLORIDA.

The output of pineapples from Florida is quite variable. It has exceeded a million crates in a single year. During 1914 it is doubtful whether the shipments amounted to more than a quarter of a million crates. This shrinkage is to be accounted for by the severe frosts of the preceding winter. Florida appears to be so well adapted to

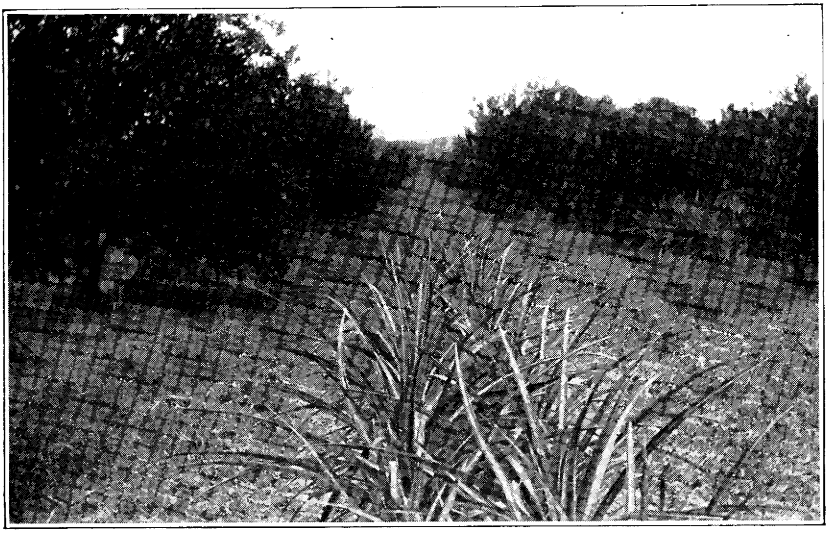

FIG. 1.—CITRUS ORCHARD WITH PINEAPPLE INTERPLANTING IN PORTO RICO.

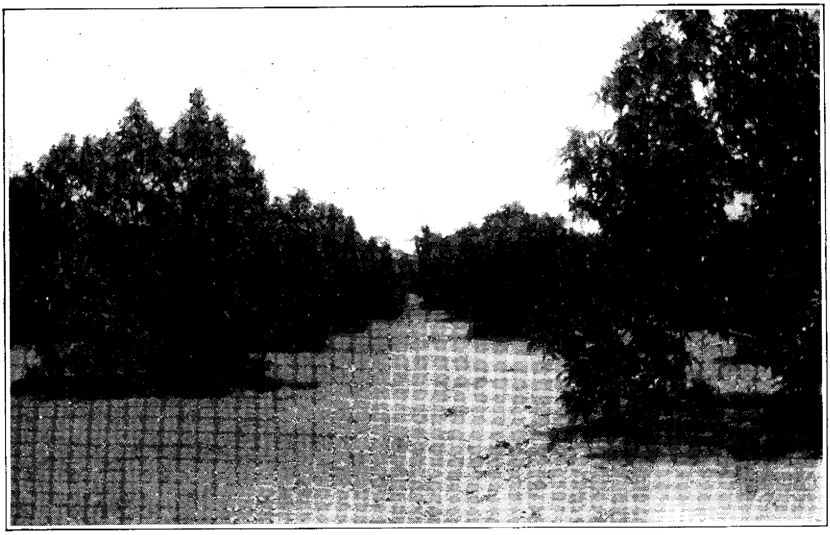

FIG. 2.—VIEW IN A 20-ACRE AVOCADO ORCHARD IN FLORIDA.

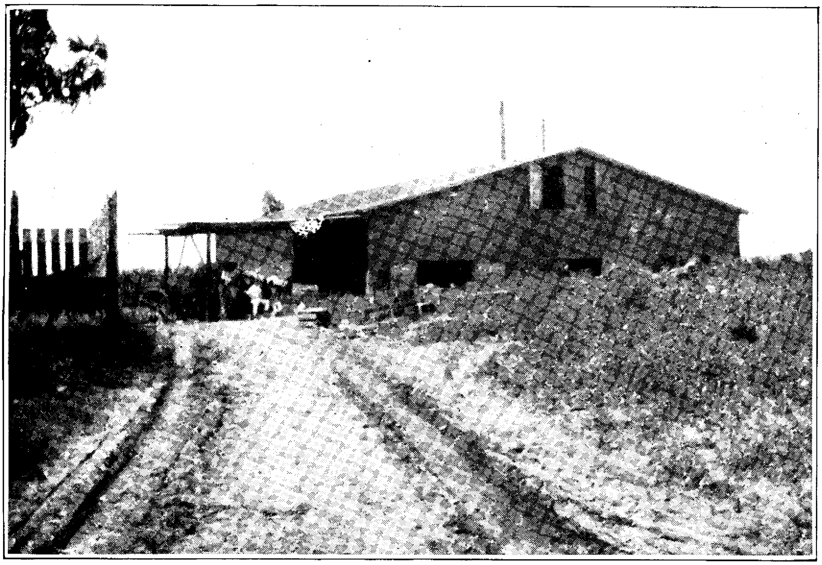

FIG. 1.—A PINEAPPLE CANNERY NEAR SAN JUAN, PORTO RICO.

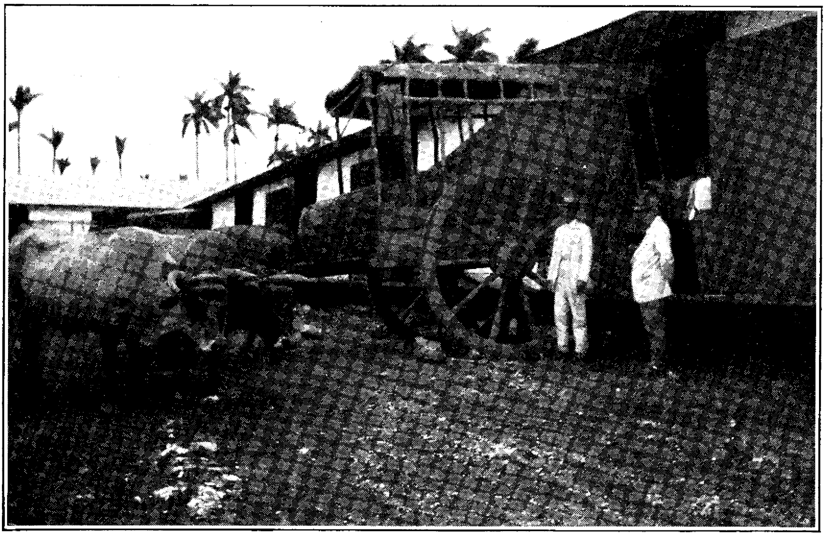

FIG. 2.—A BULLOCK WAGON DELIVERING PINEAPPLES IN BULK AT THE PACKING HOUSE IN CUBA.

other horticultural crops—such as grapefruit, oranges, and early vegetables—that the production of pineapples may not be greatly extended.

The pineapple industry of Florida is divided into comparatively small holdings, by far the larger portion of the crop being grown by individuals or small companies. Practically the entire output is shipped as fresh fruit, the canning trade being almost negligible in this State. Some of the pineapples shipped fresh from Florida, as well as from Cuba and Porto Rico, find their way into the canneries of the United States, notably in the neighborhood of Baltimore.

The pineapple area in Florida is confined chiefly to a comparatively narrow zone along the eastern coast line of the southern part of the State, centering about Fort Pierce. The soils are almost pure sand, with a small admixture of humus. These soils, when heavily fertilized, produce very fine crops of pineapples. The arrangement and spacing of plants is much the same as that described for Porto Rico. The bed system is quite frequently found.

The Red Spanish is almost the universal variety and seems well adapted to the soils and conditions of that region. The variety Abachi, mentioned above, is grown to some extent, and skillful shippers succeed in placing it safely in the northern markets, although it is much more susceptible to injury in transit than is the Red Spanish.

Among diseases and insects in Florida may be mentioned wilt and the pineapple scale and mealy bug. Wilt has been quite prevalent and has caused heavy losses. The means for controlling the mealy bug and scale are similar to those mentioned in the discussion of the Porto Rican industry. It was found that some growers were protecting their fruits from sun scald by covering them with small pieces of cotton or other rough material where they had broken over and were lying exposed to the sun.

The fruit is shipped in crates of the same size as those mentioned above and goes chiefly to the large eastern markets, but is sometimes found as far west as San Francisco. There is not the organization of pineapple growers for the marketing of the crop that is found in the case of the citrus growers of the State, who are well organized. Many of the pineapples are shipped through commercial firms in Jacksonville. Florida, although nearer the great markets, is said to have a disadvantage in freight rates, the charge, for example, being 48 cents per crate from Miami to Cincinnati, while from Havana to the same destination it is only 29 cents. The Florida fruit has a long haul by rail before it reaches the market, but it is packed and handled so much better than Cuban fruit that the profits have probably been greater in Florida than in Cuba.

SUMMARY OF OUTPUT OF FRESH PINEAPPLES IN COUNTRIES VISITED.

In round numbers the output of fresh pineapples in the countries visited may be summarized as follows:

	Crates.
Florida	600, 000
Cuba	1, 250, 000
Porto Rico	650, 000
Total	2, 500, 000

Estimated on a basis of 72 pounds per crate, the total crop would be about 90,000 tons. The output of Hawaii in the form of canned pineapple for 1914 was approximately 2,250,000 cases or about 90,000 tons. The fresh fruit export of Hawaii amounts to only a few thousand tons. Florida, Cuba, and Porto Rico sell as much fresh fruit as Hawaii sells in cans.

CITRUS FRUITS.

The citrus industries of Porto Rico are rapidly increasing in importance. The grapefruit has made the most rapid advance, increasing in value from a little over $7,000 in 1907 to nearly $752,000 in 1914, when it equaled the orange output and at the present rate of development will soon surpass it. Porto Rico seems to be peculiarly adapted to the growth of this fruit, the trees bearing abundantly and the fruits, when well grown, being equal in quality to any of those with which they come into competition and superior to many. The business is as yet young, and although handled in a modern manner, many advances in methods of cultivation and marketing will doubtless be made.

Oranges grow on almost every finca, or farm, where they have been planted for coffee shade or for fruit production, but have received, in many cases, little or no attention. These are the seedling oranges which are in the local markets during a large part of the year, coming first from the lowlands and later from the altura, or high country. Late in the winter these fruits become well colored and are excellent for domestic consumption. Considerable shipments of these are also made to the United States, where in seasons of high prices they bring enough to pay a small profit to the shipper. The methods of handling these oranges, however, are far from satisfactory, since the growers are wholly unfamiliar with commercial methods of culture, handling, and packing.

Probably the larger part of the oranges shipped from Porto Rico is grown in orchards and handled in as modern a manner as could be expected in the early stages of the development of the industry. These orchards, budded to commercial varieties, are owned and controlled by Americans almost exclusively. The Porto Ricans themselves have not adopted this type of cultivation.

The lemon is not produced in Porto Rico to any considerable extent, although there are some trial plantings on the south side of the island. The orchards of oranges and grapefruit just referred to are along the north side of the island in much the same localities as the pineapple.

In methods of cultivation there are some other points which are worthy of notice. The use of cover crops is notably on the increase, the jack bean (*Canavali ensiformis*) having proved of great value there, as it has in Hawaii. At most seasons of the year in the citrus districts there is an abundance of rain to maintain the trees, and the cover crop, which prevents the soil from washing, adds nitrogen, and maintains the supply of humus. In some cases grass has been allowed to grow under the trees, and some growers claim that the results have been very satisfactory.

The prevailing winds necessitate permanent and effective windbreaks, and one of the striking aspects of the landscape is the windbreak of bamboo about these orchards. Under Porto Rican conditions, the bamboo lends itself well to this use, making a rather thick mass of foliage through which the wind sifts slowly.

Porto Rico appears to have a comparatively easy task in the control of scale insects which add so much to the expense of citrus culture in many parts of the world. Nearly all the common scale insects of citrus are found in the island, but most of them are held well in check by fungi. The red fungus (*Sphærostilbe coccophila*), the gray fungus (*Ophionectria coccicola*), and several species of black fungi are found to hold the scales under control. The relation of windbreaks to the control of insects by fungi is important. In exposed places, the fungi do not prosper sufficiently to be an effective means of control. The windbreaks, therefore, serve a double purpose in protecting the trees from wind injury and in assisting the warfare against insects. It is not generally found necessary to distribute these fungi by spraying or other artificial means. The attempt is being made to introduce these beneficial fungi into Hawaii. It is not to be expected that they will prove as effective in the dry climate of Honolulu, but in many humid localities, such as Hilo, Puna, and the Kona district of Hawaii, it is not improbable that these fungi would be a great aid in controlling the purple scale and the Florida red scale, which are so prevalent in these islands.

Aleyrodes howardi, related to the white fly (*A. citri*) which has given so much trouble to the citrus growers of Florida, is found in Porto Rico and is said to be a native species. It affects the orange, as well as a long list of other plants, but is not of so much economic importance, probably on account of its being parasitized by a hymenopterous insect not yet identified. *Pseudococcus citri* is said to be held well in control by the Australian species of ladybird (*Cryptolæmus montrouzieri*).

In Cuba the brevity of the visit made it impossible to do more than take a passing glance at the citrus development which has taken place in recent years. There are a great many small citrus holdings and a number of very large plantations of oranges and grapefruit, considerable American capital having been invested in that island. There is a large local consumption of oranges, many of these being shipped to the markets of Havana and the other large cities of the island. The larger part, however, is shipped to the United States. Because of the almost unlimited extent of land available at comparatively low prices, and because of the proximity to the American markets, there appears to be opportunity for much greater development. Many citrus orchards, however, have been planted and abandoned for one cause or another. Some of these have been on land unsuitable for their culture.

A striking feature in some of the Cuban citrus groves was the presence of grass, which has also been mentioned as having been found, but to a less degree, in Porto Rico. Many growers of citrus trees in Cuba claim that they have obtained better results by this method than by any other which has been tried. Whether a thorough test of leguminous cover crops has been made was not determined.

Scale insects are controlled by the same means as in Porto Rico. In all places visited, fumigation was never practiced, and spraying was used chiefly as a means of controlling the rust mite. This pest is very common and injures a large amount of fruit, which, although not affected in quality, is so badly injured in appearance as to seriously reduce the price. By means of the usual sprays, notably sulphur, the injury can be kept down to negligible proportions.

An orchard wagon of American manufacture seen in Cuba is worthy of mention as being possibly adapted to use in the pineapple fields of Hawaii. The peculiarity of this wagon is that the rear wheels follow exactly in the track of the front wheels. This prevents injury to many plants because not a few drivers who are able to drive well enough to get the front wheels away from the plants, run over them with the rear wheels of the ordinary wagon. Some of the pineapple growers of Hawaii are interested in further investigation of this type of wagon.

The citrus industries of Florida are older and more highly organized than those of Porto Rico and Cuba. The brief visit in this State permitted only a glance at a small part of the industry. Some of the matters which have been mentioned in connection with the citrus industries in Cuba and Porto Rico also impressed themselves here. The efficiency of the parasitic fungi on some of the citrus scales was apparent. This, together with spraying for certain scales and for the rust mite, has resulted in very clean, bright fruit in many of the groves.

The highly organized system for the marketing of citrus fruits is worthy of special note. The Florida Citrus Exchange handles approximately 25 per cent of the output. The estimated crop for the 1914–15 season was about 7,000,000 boxes, of which the Florida Citrus Exchange probably handled from 1,500,000 to 2,000,000 boxes. This is an organization of producers and has done much to systematize marketing and bring satisfactory returns to the grower. The details of its organization can not be gone into here.

One of the most talked of subjects in citrus circles at the time of the visit was the citrus canker, a disease which had recently made its appearance in two widely separated parts of the State, one area of infestation being in the southern part, in Dade County, and the other in the extreme north, at Monticello, quite close to the Georgia line. This disease affects the foliage, the branches, and the fruits of several species of citrus, being notably a pest of the grapefruit, for the excellence of which Florida has become famous. This disease, which has also been found in most of the Gulf States where citrus is grown, appears to be very difficult of control. The energetic manner in which the growers and the Government are attempting to eradicate the disease from Florida is noteworthy. The warfare has passed from the stage of spraying and even of cutting down whole orchards to the use of an oil-burning torch especially constructed for the purpose. It was found that by the cutting down of the trees the operators themselves spread the disease. The torch is now applied without the operators coming in contact with the trees. So vigorous is the warfare that every tree that shows the slightest infection is burned to the surface of the ground. The soil also is treated in like manner. Whatever may be the outcome of the struggle, no efforts are being spared to rid the State of this serious disease.

The overhead systems of irrigation which have been installed in some citrus orchards attract attention. These have proved valuable not only as a means of supplying the trees with water but also in fighting frosts. The application of an artificial shower to the trees is a very decided protection during cold nights. Many growers feel that the system is worth all that it costs, either as a means of irrigation or protection against frosts.

Florida has been somewhat prolific in varieties of citrus fruits. A new orange, known as the Lue Gim Gong, which originated at De Land, is attracting much attention at the present time. Its special merit appears to be in its holding firm to the tree after it has become ripe and well colored. It is said that it will hold on the tree for a year or more, enabling the grower to extend the shipping season for his fruit. It is described as "a late round orange of unusual merit."

Another of the originations of Florida now coming into some prominence is the Foster grapefruit, said to be a bud mutation from the variety Walters, which it very closely resembles in all particulars, except that the Foster has pink flesh, a new feature among the pomelos grown in the United States or the West Indies. Both of these varieties are now growing in Hawaii, and a limited supply of budwood will soon be available.

THE AVOCADO.

The avocado is claiming a place of considerable commercial importance in Florida and in California, but the West Indies do not appear to have awakened to the possibilities of profit in this unusual fruit. In Florida there are orchards of 25 to 30 acres, some of them now in bearing, while new plantings are constantly being made, particularly in the area along the east coast from Palm Beach southward (Pl. VII, fig. 2). The natural limitations of successful culture have not yet been determined, and there appears to be less tendency to emphasize the hardy varieties than in California. The avocado does not appear to be lacking in vigor and productivity in the parts of Florida referred to. This State possesses an unusual advantage in its proximity to great markets where its fruits can be placed about two days after picking, thus avoiding the need of refrigeration. The Trapp is the leading commercial variety and has many points in its favor, being in season when the markets are no longer glutted with northern fruits, and having a good form for packing and good keeping qualities. It is one of the easiest varieties to bud. The methods of budding are essentially the same as those which have been found adapted to conditions in Hawaii. In general practice, the bud is tied with only a waxed bandage which remains in place about 17 days, after which the bud is forced into growth by cutting back a few inches at the top of the stock and later removing its buds as they start into growth. There is a strong tendency to bud stocks in shingle boxes or other containers rather than in the nursery row, due in part to the Florida soils being not suited to the practice of lifting nursery plants with a ball of soil.

Porto Rico is rich in very excellent varieties of avocados, or aguacates, as they are known there and in other Spanish-speaking countries. The lack of effort to propagate by budding may be due in part to the high average of excellence among seedlings, but more probably to the fact that the commercial possibilities of this fruit have not yet been recognized. With a three or four day service direct to New York, a season that could be made to cover nearly the entire year, varieties that need only to be sought out, standardized, and propagated by buds, and a climate in which the conditions are ideal and the danger of frost unknown, there appear to be opportunities that would appeal strongly to the enterprising fruit growers of California or Florida. The American fruit grower in Porto Rico is busy establishing his citrus and pineapple industries, which are yet young, and the native Porto Rican has not taken very enthusiastically to any line of fruit production.

Porto Rico doubtless has some varieties worthy of introduction into Hawaii, particularly choice early and late sorts to lengthen the season. This could be done at the present time by searching out the seedling trees, but when Porto Rican varieties have become standardized, it will be an easy matter to make the introductions by means of budwood which may be safely carried through the mails.

In Cuba, the price of avocados in July was a striking feature. Good-sized fruits were selling in Havana at 20 to 25 cents Spanish money,[1] and exceptionally good fruits are said to bring 10 cents each even in the height of the season. In the country districts, it was found necessary to pay 5 cents each for ordinarily good fruits in July, which, while not mid season, can not be regarded as out of season. It is said that they become quite cheap for a short time when they are most abundant.

There appears to be very little commercial culture of the avocado in Cuba, but interest in it is beginning to be aroused. The very large consumption of the fruit in Havana itself and the proximity to the American markets, with direct and frequent transportation, would seem to indicate that there are possibilities in the culture of the avocado here which will grow in importance as the fruit comes to be more widely known and used.

California is probably planting avocados more rapidly than any other country at the present time, plantings being made in different localities from San Diego to Butte County. In this State much emphasis is being placed upon hardy varieties, some of which are claimed to endure as much cold as the orange. These have been introduced chiefly from the highlands of Mexico. Some seedlings from Hawaiian stock were considered hardy under ordinary conditions, but many of these were unable to endure the severe cold of the season of 1912–13, when they were killed to the ground in the nursery.

In California budding in the open nursery is growing in favor, and in the heavier soils of this State it is possible to "ball" the trees for transplanting. Many new varieties are being described and propagated, and there is considerable diversity of opinion as to which of these varieties are likely to take permanent places in the avocado culture of the State.

---

[1] The Spanish dollar has a purchasing power of something over 90 cents American money.

Concerning the insects and diseases of the avocado in the countries visited, some facts were noted. The avocado mealy bug (*Pseudococcus nipæ*) was found in a city park in Mayaguez, Porto Rico, but was not seen elsewhere, and so far as could be determined, it had not been reported in the entomological records of the island, which would make it appear to be a comparatively recent introduction. The same species was found in one of the orchards in south Florida, but elsewhere was not seen, and appeared to be unknown to avocado growers, indicating that it is probably a recent introduction in Florida also.

No avocado borer (*Xyleborus* sp.) was seen or reported in any of the countries visited. The larva of an insect, locally known in Cuba as the bagworm, is said to eat the foliage of the trees. It is not reported as a very serious pest. Red spiders appear to be generally distributed and do slight injury, as in Hawaii. A disease first affecting the roots but later involving the trunk also, was reported in Cuba and was said to be somewhat serious. It was not seen and its identity has not been learned.

THE MANGO.

The mango has been planted on a commercial scale by at least one company in Porto Rico. The trees are vigorous and some varieties bear abundantly. The problem of determining the varieties best suited to local conditions is now being worked out. These have to be selected with reference to several factors, notably, varietal resistance to the mango fruit fly and to the mango blight. The mango fly (*Anastrepha fraterculus*) is similar in habit to the Mediterranean fruit fly, with which every one in Hawaii is now familiar. Varieties show marked differences in resistance. The Sandersha, for example, which is one of the largest and finest in appearance, as well as a most prolific bearer, is also one of the most susceptible to the fly.

The mango blight (*Glœosporium mangiferæ*) is prevalent in the moister parts of Porto Rico, as in Hawaii, but some varieties are quite resistant. On the dry side of the island, with irrigation, this disease would do practically no injury.

One of the most promising varieties in Porto Rico is Amini, of East Indian origin. It very closely resembles Pirie, is said to be free from the attacks of the fly, and grafts readily on the native stock.

Piña (pineapple) is one of the so-called native varieties and is worthy of some attention. It has very little fiber, is of good flavor, and is quite resistant to the mango fly.

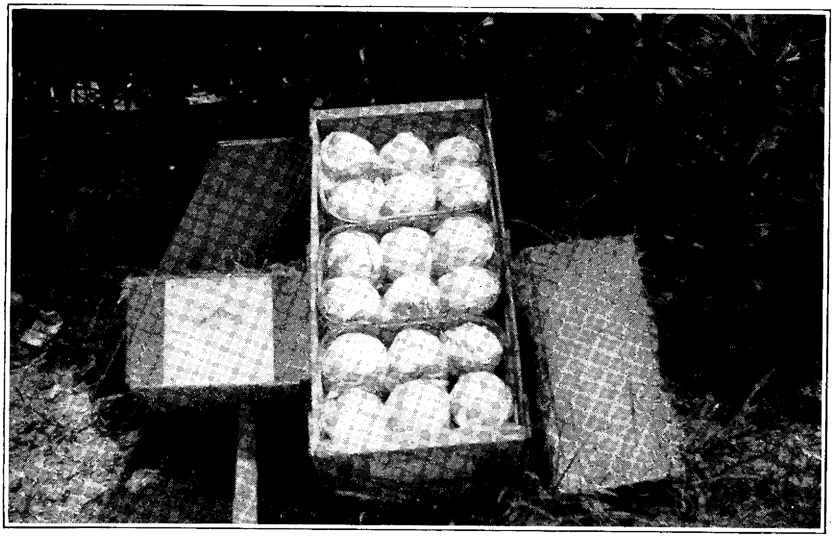

FIG. 1.—CRATES OF MANGOES AS THEY ARE PACKED IN FLORIDA.

Note the three different sizes of crates.

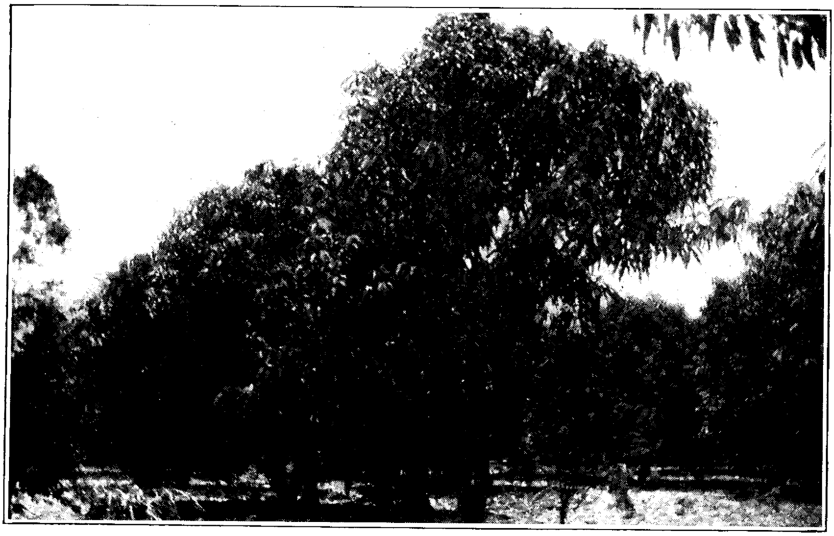

FIG. 2.—A TREE TOP-WORKED TO THE HADEN MANGO.

Hueva del Toro is one of the most common of the Porto Rican mangoes. It is of good appearance and fair flavor, but is somewhat fibrous and extremely subject to the attacks of the fly. It is very similar to the Hawaiian sweet mango.

In addition to several varieties of mangoes that have been introduced by the United States Department of Agriculture, three East Indian varieties have been introduced by the Misses Leitch, of Garrochales, who are making every effort to establish the mango on a commercial basis in Porto Rico. The varieties are known as Champaddan, Colombo Kidney, and Ceylon Horse House. The Colombo Kidney was seen and tasted and proved to be of excellent flavor and very fine texture.

A method of bark grafting the mango has been devised by the Porto Rico Experiment Station and is now being used by a number of fruit growers. This method has been found well adapted to Hawaiian conditions. (See p. 22.)

In Cuba there are a few commercial plantings of the mango and many of the East Indian varieties are being tested. Among the established forms that have long been in the islands, it is interesting to note the points of relationship to those of Hawaii. The variety known in Cuba as Manila is very similar to, if not identical with, that known in Hawaii as Pointed Chutney. It is of delicious subacid flavor and is free from fiber. The Seda is the same as that known in Hawaii as the No. 9, of which there are several forms all tending to the "S" shape and all of mild flavor and rather fibrous texture. Criollo closely resembles the variety in Hawaii known as the Double-Pointed Manila.

Florida has made substantial progress in establishing a mango industry, and small commercial shipments are being made regularly in season. (Pl. IX, fig. 1.) Budding is done in the nursery row and also in pots, and many varieties are being tested. The Mulgoba has been more generally planted than any other and is certainly a very fine mango as grown in Florida, where it acquires a good color. It is said to be a somewhat uncertain bearer, and growers are hoping for much from its seedling, the Haden, which is just now attracting attention and gives promise of being a heavier and more regular bearer (Pl. IX, fig. 2).

The establishment of the mango on a commercial basis is necessarily a slow process, but there can be no doubt of the ultimate outcome in countries adapted to its culture and able to ship the fruits to large markets. The best mangoes appeal to the average taste and are most attractive in appearance.

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HAWAII AGRICULTURAL EXPERIMENT STATION,

J. M. WESTGATE, Agronomist in Charge.

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION.

1916.

UNDER THE SUPERVISION OF
STATES RELATIONS SERVICE,
Office of Experiment Stations,
U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the States Relations Service, United States Department of Agriculture.]

E. W. ALLEN, *Chief of Office of Experiment Stations.*
WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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ALICE R. THOMPSON, *Assistant Chemist.*
C. A. SAHR, *Assistant Agronomist.*
A. T. LONGLEY, *In Charge of Cooperative Marketing Investigations.*
J. W. LOVE, *Executive Clerk.*

LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, July 17, 1916.

SIR: I have the honor to transmit herewith and to recommend for publication a report of the Hawaii Agricultural Experiment Station, 1916.

Respectfully,

J. M. WESTGATE,
Agronomist in Charge.

DR. A. C. TRUE,
Director States Relations Service,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
D. F. HOUSTON,
Secretary of Agriculture.

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REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1916.

SUMMARY OF INVESTIGATIONS.

By J. M. WESTGATE, *Agronomist in Charge.*

BUILDINGS AND GROUNDS.

During the year the only new building erected on the station grounds was a one-room cottage for one of the laborers, whose duties necessitated his constant presence on the station grounds. A considerable number of the laborers' quarters and two of the station residences were in such condition that rather extensive repairs were considered necessary.

The grounds available for station work were materially increased by the setting aside of a 13-acre tract on the Schofield Barracks Military Reservation for use as a forage-crop experimental tract. The land available at the central station at Honolulu is not typical of much of the grass and hay land of the islands, and it is thought that the results obtained in the new location will have a wider application than would be secured were the proposed work carried out at Honolulu.

CHANGES IN THE STAFF.

The scientific staff of the station shows a number of important changes when compared with that of the preceding year. M. O. Johnson was transferred July 25, 1915, from the chemical work of the Bureau of Animal Industry, United States Department of Agriculture, to succeed W. T. McGeorge as chemist, the latter having been transferred to the Bureau of Chemistry July 8, 1915. On March 1, 1916, Miss Alice R. Thompson was transferred to the Bureau of Chemistry for a year's special work on fruits and fruit wastes. C. W. Carpenter was added to the staff as pathologist by transfer on June 1, 1915, from the Bureau of Plant Industry. J. B. Thompson was appointed assistant agronomist July 6, 1915, to become superintendent of the Glenwood substation, succeeding F. A. Clowes, who resigned on July 1, 1915, to take charge of the agricultural department of the Lahainaluna Boys' Industrial School, at Lahaina, Maui. On June 30, 1916, A. T. Longley, in charge of cooperative-marketing investigations and executive clerk of the station, was furloughed to the Territory of Hawaii so that he might devote his entire time to his duties as superintendent of the Territorial marketing division, which is carried on under the general supervision of this station. He was succeeded as executive clerk of the station by J. W. Love, who was transferred May 10, 1916, from the States Relations Service, Washington, D. C. On May 31, 1916, John McCoy resigned as collaborator. His place was filled by A. L. Arthur under an appointment becoming effective July 1, 1916.

ECONOMIC COLLECTIONS.

The numerous requests for identification of various plant diseases, fruits, grasses, legumes, and other forage and green manure crops have for some time indicated the need of a collection on the station grounds of the more important species and varieties. With this end in view a four-section herbarium case was purchased, and collections of native and introduced species of grasses and legumes, as well as of economic fungi, have been started. The fruit and other bulky specimens are being preserved in museum jars. It is planned to supplement the specimens with a file containing all available data concerning the species and varieties in question. Much of the preserved material will be available for displays at the local agricultural fairs, which constitute a new enterprise of great interest to the station.

COOPERATION WITH MILITARY POSTS.

The numerous military posts located in different parts of the island of Oahu have afforded considerable opportunity for cooperative work during the past year. The station has rendered active assistance in the efforts to establish suitable growth according to systematic planting plans for each of the military posts and reservations. Instead of cooperating with individual officers, the station has attempted, as far as possible, to have all requests for planting material come through a single representative of the Army, it being much more practicable for the station to respond to a single request for large supplies of material than to numerous requests for small amounts.

A second and more important activity from an economic standpoint has been the cooperative work in the establishment of locally grown forage grasses for feeding the Army horses and mules. A number of preliminary plantings have been made on the Schofield Barracks Military Reservation, where probably 1,000 acres of potential grass land is available for the production of such grasses and other forage crops as may be shown to be adapted to the purpose. The seeds for these plantings have been largely furnished by the station, while the actual planting operations have been conducted by the Army. During the coming year it will probably be practicable for the station to do most of the planting with its own labor.

On June 10, 1916, the station received notification from the United States Army quartermaster at Schofield Barracks that the commanding officer of the Hawaiian Department had approved the setting aside of a 13-acre tract at Schofield Barracks, and that the same had been set aside for the use of the station as an experimental tract upon which to test the best methods of growing forage for the Army horses and mules. Preliminary plantings by the Army in cooperation with this station have already been made on 9 acres of this tract. One of the handicaps under which the work is conducted at Schofield Barracks is the fact that, although there is an annual rainfall of about 35 inches, yet this occurs as torrential rains during the winter season, or in the form of light showers which do not penetrate deeply, especially if the soil is at all compact. Furthermore, the soil in question does not have normal water storage capacity.

ALGAROBA INVESTIGATIONS.

The increasing importance of the algaroba has led to the inauguration of some new lines of work which promise to develop into an important station project. There has been some discussion as to the native home of this tree which was introduced into Hawaii nearly a century ago and which has since assumed great importance as a source of firewood, honey (flowers), and cattle feed (pods). It has been claimed that it is one of the mesquites of the southwestern United States which, on being transferred to the more favorable climate of Hawaii, has developed into a large tree. A comparison with several available forms of the mesquite seems to indicate that it is a different species. In cooperation with the Bureau of Plant Industry, United States Department of Agriculture, seeds from various species of the genus Prosopis have been obtained, and as fast as these are received they are planted on the station grounds. It is expected that ultimately one or more lots of the seedlings will develop into trees comparable with the local algaroba grown under similar conditions. This will furnish a clue to the original source of the local species. It seems probable that the species is a South American one.[1]

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[1] In a magazine entitled "Peru of To-day," an illustration, published some three years ago, was noted as picturing trees resembling very closely the local algaroba tree, while the statements regarding the character and utilization of the pods furnished further evidence that the local tree may come from the same stock as the South American species.

HORTICULTURAL INVESTIGATIONS.

The pineapple work has continued to occupy an important place in the activities of the horticultural division. The seedlings reported upon in the annual reports for 1913 and 1914 have now fruited. The showing made by the first set of seedlings was such that special efforts were made to obtain another supply of seeds, which occur so rarely in cultivated pineapples. By singular good fortune the station was able during the past year to obtain several thousand seeds through the courtesy of the management of the pineapple canneries of Libby, McNeill & Libby of Honolulu (Ltd.), the Hawaiian Pineapple Co. (Ltd.), and others. The wide variation shown in the former plantings makes it probable that the present new plantings will show some promising variations.

The work of assembling pineapple varieties from other parts of the world is progressing favorably. It is thought that there may already be in existence pineapple varieties which will prove superior in Hawaii or may be of use in cross-pollination experiments for the development of especially adapted varieties.

The work with the litchi has been mainly in developing methods of controlling the erinose disease, which is threatening some of the best trees in the islands. Considerable attention has also been given to the question of improved stocks for grafting and budding. The seeds are peculiar in that after removal from the fruit they either sprout or dry up and die within a week. This characteristic has in the past prevented the shipment of seed for long distances. Methods recently developed have been so successful that seeds have been sent as far as Florida, arriving there in excellent condition for immediate planting.

Plant-breeding work with mangoes, avocados, and papayas has been carried on during the flowering seasons of these species. The peculiar requirements of the different species have necessitated the development of a special technique in each case in order to obtain satisfactory setting of fruits. Apparent hybrids have been produced between the Chinese wood-oil nut and the Hawaiian kukui nut, it being desired to develop a hybrid the oil from the nuts of which shall be intermediate in certain characters between the oil of the parent trees, a result greatly desired by commercial dealers in drying oils.

Numerous plantings of various species of tropical plants, mostly trees, have been made during past years at the Tantalus substation, situated, at an altitude of about 1,000 feet, at the upper end of the experiment station reservation. The histories of the individual plantings are being worked up, and those completed to date have been included in this report as a matter of record.

The distributions of plant material have been largely confined to hibiscus cuttings, spineless cactus slabs, citrus seedling stocks, citrus budwood, budded seedlings of avocado and mango, and seeds of papaya. It has been decided to discontinue the distribution of plants as soon as they pass beyond the experimental stage and become suitable for commercial handling.

CHEMICAL INVESTIGATIONS.

With the recognition of the necessity for the maintenance of the humus and nitrogen content of island soils, the rôle of the various available leguminous plants becomes increasingly important. There are over a score of cultivated and wild species which are more or less efficient as green manure crops for keeping up the fertility of the soil. In order to determine which of the species are most efficient as green manures, a series of experiments has been carried out and the results submitted for publication. Those legumes should be grown the seed of which is available and which make the best growth under prevailing conditions. A number of wild legumes were found to be worthy of further test as green manure crops. It has also been found that the succeeding crop should be planted as soon as possible after the legume crop has been turned under, as the nitrate leaches rapidly from the soil and is thus lost to the new crop.

The importance of the pineapple industry has led the chemical division to devote considerable time to the pineapple problems of the islands. The "Kauai pineapple wilt" is proving most troublesome on the island of Kauai. This wilt seems to be correlated with the presence of a certain soil type, and experiments are under way to determine what treatment of such areas is most effective.

The yellowing of pineapple plants on many of the pineapple plantations on the island of Oahu was determined some years ago by this station to be due in some way to the presence of large quantities of manganese in all areas producing this effect. All the details of just how the presence of manganese induces the unhealthy condition of the plants were not worked out, however. It is believed by the present chemist that the presence of manganese so inhibits the absorption of iron by the plant that chlorosis rapidly develops. This happens in spite of the fact that the soils in question are very heavily impregnated with iron compounds, as much as 30 per cent of ferric oxid occurring at times. With the recognition that the real trouble was chlorosis, due to lack of iron in the plant itself, the standard remedy for chlorosis due to lack of iron at once suggested itself. A solution of iron sulphate was applied to the plants both as a spray and with a brush. The result was very marked, the yellow plants rapidly taking on a rich green color and the undersized, red, and stunted fruits soon becoming normal. Experiments are under way to determine the most economical iron compound to use, the number of applications necessary, the optimum strength of the solution, and other practical points arising in connection with the application of the solution on a commercial scale where thousands of acres must be treated with the greatest possible economy of time and labor.

Some studies were made regarding the hydrocyanic acid content of cassava, which is coming into some prominence as a source of starch, while the waste gives promise of value as a feed for hogs. An improved method for determining small amounts of hydrocyanic acid has been developed by the chemist during the year and an account of the method published.

An analysis of the edible canna indicated that it possesses about the same food value, pound for pound, as does the Irish potato. This work will be followed up, as the production of Irish potatoes on the islands is a most hazardous undertaking, due to the ravages of blight and related diseases.

PLANT-DISEASE INVESTIGATIONS.

The division of plant pathology was inaugurated June 1, 1916, by the transfer of the present pathologist from a similar line of work in the Bureau of Plant Industry, United States Department of Agriculture. A large part of the necessary equipment was purchased before he left Washington so that as little delay as possible would ensue in equipping the pathological laboratory for the study of the various plant diseases in the islands. A number of harmful diseases have been definitely located and studies already have been commenced concerning late blight of Irish potatoes and a leaf spot of sweet potato. Preliminary observations also have been made on the late blight of celery. Wilt of banana, taro rot, and anthracnose diseases of avocado and mango will also be investigated as rapidly as possible.

AGRONOMIC INVESTIGATIONS.

Work with such food crops as rice, taro, and potatoes has been continued largely in cooperation with commercial growers. The potato industry continues to be hampered by the diseases which seldom fail to destroy the crop. The plantings of velvet, muth, and kulthi beans have shown these crops to be especially promising as green manure plants. A promising shrub (*Crotalaria madurensis*) for use in coffee nurseries has been under test again this past year. It is able to withstand, and in fact thrives best under, considerable shade. Various clovers have been tried at the central station, but the low altitude appears to be unfavorable to their best growth. They are not to be recommended except possibly for the higher elevations, where they ought to furnish pasturage, hay, or green cut feed. Tests with small grains indicated promise for the production of grain hay, but the yields of grain thus far have not been such as to make it possible for them to compete with imported grains. The tests with the grain sorghums as a source of grain for feeding stock were much more satisfactory. A number of these sorghums are especially promising as chicken feed. At present most of the grain for feeding the numerous flocks of chickens in the islands has to be imported. In order to obtain material for crossing Japanese sugar cane with ordinary sugar cane a plat of the former is being allowed to stand indefinitely to determine whether it will flower in this latitude.

A considerable amount of work, agronomic in character, has been accomplished at the substations and demonstration farms. In most instances this work has been undertaken to solve some pressing local problem, but many of the results are of wider application, at least in a general way.

EXTENSION WORK.

Through the extension features of its work the experiment station comes into closest contact with the small farmer and his farm. The extension division has worked out several methods whereby the farmer can be made familiar with the best agricultural practices, as well as the best varieties and kinds, of crops to grow. The difficulties of travel and the remoteness and isolation of many of the farming districts naturally handicap the station in its attempts to reach such sections except at irregular and infrequent intervals. These rather infrequent visits are supplemented in a number of ways. Timely articles are written for the local press; local demonstrations are arranged on the land of the leading farmers in a given section; and attention is called to the fact that individual problems will at all times be given attention by letter and, if practicable, by a personal visit on the next trip to the section in question. Also, a number of farms are devoted primarily to the development and demonstration of the best agricultural practices for the sections in which they are located. These also serve as sources of supply for seeds and cuttings of the improved varieties constantly being distributed.

It has become increasingly evident here as elsewhere that the problems of marketing farm crops are quite as important as their production. To this end farmers' cooperative organizations have been encouraged to standardize their products, study the market requirements, and develop cooperative buying and selling to as great an extent as appears to be practicable. Remarkable interest is being manifested in the two county fairs, preparations for which have been under way for some months. The station is utilizing these opportunities to bring home to the visiting farmers many of the object lessons it wishes to teach.

GLENWOOD SUBSTATION.

The Glenwood substation, which has been carried on in cooperation with the Territory of Hawaii, was organized in part as an experiment station and in part as a demonstration of the possibilities of small farming operations under the extremely rainy conditions prevailing throughout the section in question. Some idea of the difficulties under which a farmer must work in this section may be obtained from the Weather Bureau records for the station, commencing January 1, 1916, which show only 9 clear days and a rainfall of 121.52 inches for the 6 months ending June 30, 1916. The same period shows 154 rainy days, June taking the lead with 30 rainy days. The principal work has been carried on with the dairy herd and the poultry flock. The demonstration of the importance of testing the weight as well as the number of eggs laid by an individual hen is probably the most important contribution of the station to the advance of poultry breeding. The studies on the development of feed stuffs which can be grown locally have also brought promising results. The edible canna not only promises well as a hog feed, but culinary tests with it as human food indicate that in emergencies the canna could without hardship be substituted for potatoes. It is a rapid-growing, heavy-yielding crop which might also be utilized as a commercial source of starch. The tops furnish a large amount of green forage which is eaten readily by cattle and poultry. Jerusalem artichokes have also given promising results, although they apparently must be dug only when needed on account of rapid decay after digging. Provision was made by the last Territorial legislature for necessary traveling expenses of the superintendent of the substation while on demonstration trips on the island of Hawaii. Unfortunately, no provision was made for the employment of a substitute while the superintendent was away on such trips, and the necessity of maintaining the records at the station prevented his absence from the station for more than a few hours at a time. He has, therefore, been able to do extension work on only a very few occasions, when some member of the staff of the central station was able to substitute for him at Glenwood. Considerable extension work has been done, however, members of the central station staff using the Glenwood substation as a base of operations.

TERRITORIAL MARKETING DIVISION.

The last session of the Territorial legislature made an appropriation of $12,000 a year for the running expenses of the Territorial market and $14,400 for a market building. In addition $7,500 was made available as a revolving fund for use as a working capital. The division has continued to lend its efforts to the service of the small farmer on the one hand and to the convenience of the consumer on the other. The new quarters are conveniently located and contain retail, wholesale, and storage rooms, as well as rooms for candling eggs, fumigating seeds, etc., and dressing poultry.

The need of an outlet for surplus products led to the establishment on July 1, 1915, of a marketing branch in San Francisco. This branch has been reasonably successful in handling miscellaneous shipments, but the pineapple shipments were not a success, owing to heavy spoilage and glutted markets.

More and more attention is being paid to the grading and packing of farm produce. It is not easy for the isolated producer to realize the advantage in catering to the better class of trade which demands uniform goods in uniform packages. The division is planning to provide at cost standard containers for various forms of farm produce.

Another feature of the marketing work has been the establishment of a retail department for those desiring to do their marketing in person and thus save delivery charges. The relations established with the various producers throughout the islands make it possible for the experiment station, especially through its extension division, to keep in closer touch with the farmer and his problems than might otherwise be the case. The problems of production ordinarily are quite different from those of marketing, but by cooperation between the two lines of work it is often possible to indicate improved farm practices which will result in better products for marketing purposes.

REPORT OF THE HORTICULTURAL DIVISION.

By J. E. Higgins.

The work of the horticultural division has continued along the lines of investigation that have been pursued for some years past. Few strictly new lines have been undertaken, but a number of new projects have been developed out of older ones through increasing emphasis laid upon certain phases of horticultural activity. Some investigations relating to the pineapple industry have been carried on for a long time, but there has been no opportunity for such development as the importance of the industry in Hawaii would justify. During the year just closed it has been possible to begin some work in the breeding of pineapples upon a larger scale than formerly. The litchi has also demanded increased attention. The project relating to the top-working of the mango and the avocado by bark grafting and scion budding has been closed, the final results having confirmed those recorded in the annual report for 1915. The present tendency of the work of the horticultural division is toward larger attention to plant breeding.

PINEAPPLE INVESTIGATIONS.

The work of breeding and collecting new varieties of pineapple is believed to be of considerable importance in connection with the Hawaiian pineapple industry. There are several possible methods of procedure in this matter, the first being the collection of varieties of pineapples at present in cultivation in different parts of the world. There are few varieties that have shown sufficient merit to become established as commercial sorts. It is, however, worthy of note that kinds which have not been at all successful in some pineapple-growing countries have proved remarkably successful elsewhere. The Cayenne, for example, has never found much favor in Porto Rico, where the Red Spanish has been so successfully grown, while in Hawaii the Cayenne is almost the only commercial variety. It is not improbable, therefore, that some of the little known varieties may prove to do better when introduced into Hawaii than they have done elsewhere. Attempts have therefore been made to secure as many as possible of the world's varieties, but because of the prevalence of certain diseases it has not been possible up to the present time to secure a very large number. Through the Porto Rico Agricultural Experiment Station a considerable number of the varieties grown in that island were obtained, and later one or two additional varieties were secured in Cuba and Florida. Efforts are being made to obtain a much larger collection of varieties from different parts of the Tropics.

Another method of securing new varieties is by means of the crossing of established sorts. Since none of the introduced plants have as yet flowered, it has not been possible to carry on this phase of the work except in a very limited way with pollen which has been secured through the courtesy of a local pineapple grower who had flowering plants of the variety Queen.

A still further means of securing new varieties lies in the growing of seedlings from the plants which on rare occasions produce seeds in the commercial pineapple fields in Hawaii. Four years ago a few seeds were secured and planted, and some of the resulting plants produced their first fruits in June, 1916. These seedlings have shown as wide variations as might be expected in the crossing of any two varieties of pineapples. Some are quite vigorous, while others are almost totally lacking in vigor. Some of the plants are green in color, while others from the same seed stock show a very brilliant red coloring. In some the leaves are narrow, in others broad. Some of the plants are quite as smooth as the Cayenne, while others are extremely spiny.

During the past fiscal year several thousand pineapple seeds were secured through the cooperation of a number of the pineapple canneries. It is interesting to note how rarely these seeds occur. In fact, the canneries may in some seasons run through millions of fruits without finding any seeds. During a part of the winter season of 1915–16 seeds were found with comparative frequency in fruits brought to the canneries. For example, in a run of 63,000 fruits, 9 were found with seeds. In another run of 48,000 fruits, 4 were found with seeds. It is estimated by the weight of the seed that about 2,433 seeds were obtained from these 13 fruits. With such frequency of occurrence there should be no difficulty in securing any reasonable number of seedlings, but frequent seed bearing seems to be very unusual.

Satisfactory methods have been devised for the germination of pineapple seeds and the growing of the young seedlings beyond the critical period. There are several essential conditions which must be provided, including perfect drainage, constant and uniform moisture supply, sufficient heat, and prevention of excessive growth of algæ on the surface of the seed bed. To obtain these necessary factors the following plan has been worked out: An inch or more of broken rock is placed in the bottom of the pot and above this the pot is filled to within about 1½ inches of the rim with a porous soil, on the top of which a layer of sand about a quarter of an inch thick is placed. This sand must not be of coral origin, since the lime in the coral is extremely detrimental to young pineapple plants. Molding sand, such as is used by ironworkers, has been found satisfactory. On this sand the seeds are placed, thus securing for them perfect drainage while permitting the roots of the seedlings to penetrate easily the soil beneath. The surface of the sand is covered with coconut-fiber dust mixed with a little powdered charcoal, which retards the growth of algæ and does not bake as does soil. The whole pot is then placed in a larger pot and the intervening space is packed with moistened sphagnum moss. This prevents sudden changes in moisture conditions in a climate where earthen pots dry out quickly on the sides as well as from the upper surface. Water is never applied directly to the top of the soil but when necessary the inner pots are removed and placed in water which rises to the surface. Plate I, figure 1, shows this method of starting pineapple seedlings.

A closed glass box in the greenhouse has been found to be advantageous but not essential. The close atmosphere and high temperatures aid in the early germination of the seed. Under such conditions pineapple seedlings begin to appear about 37 days after planting, while in the open, with cool winter temperature and without the close, damp atmosphere, sometimes two months or more is required for germination.

When the seedlings begin to appear some shade is necessary. Too intense light causes the plants to lose their green color and their vigor. A cheesecloth over the plants or a thin covering of whitewash on the glass of the box is sufficient, if the lights of the greenhouse have been reduced for other kinds of plants. In Plate I, figure 2, is an illustration of young seedling pineapples with the root system and the seed coat still attached.

LITCHI INVESTIGATIONS.

The investigations of the litchi (*Litchi chinensis*) have developed into an important part of the work of the horticultural division. During the year just closed attention has been given chiefly to an investigation of methods of propagation, preservation of the seeds, and preservation and shipping of the fruits. The experiments in grafting the litchi on the longan (*Euphoria longana* or *Nephelium longana*) have been continued and have proved quite successful, so far as the making of the union is concerned. The growth is very satisfactory, but it is too early to know what may be the ultimate influence of scion and stock on each other. Budding has also been tried and, although it has not succeeded so well as bark grafting, there appears to be no reason why methods should not be worked out for the budding of the litchi either on stocks of its own species or on some related species. Now that the litchi is attracting so much attention in Florida, as well as in Hawaii and elsewhere, attention should be given to the adaptability of various stocks to different conditions. Since the litchi makes a rather slow growth, stocks of more vigorous growth might be of great advantage. A more hardy species might lessen the risks from frost in the attempt to push this industry outside the Tropics. Resistance to certain pests might also be secured in this way.

The seeds of the litchi are extremely perishable, retaining their viability under ordinary conditions only two or three days. Unless they can be preserved in some way, they must be planted immediately after being taken from the fruit. As an aid in the distribution of the species, it was important to devise means for the preservation and shipping of the seeds. Experiments conducted by the station have demonstrated the possibility of preserving the seeds for

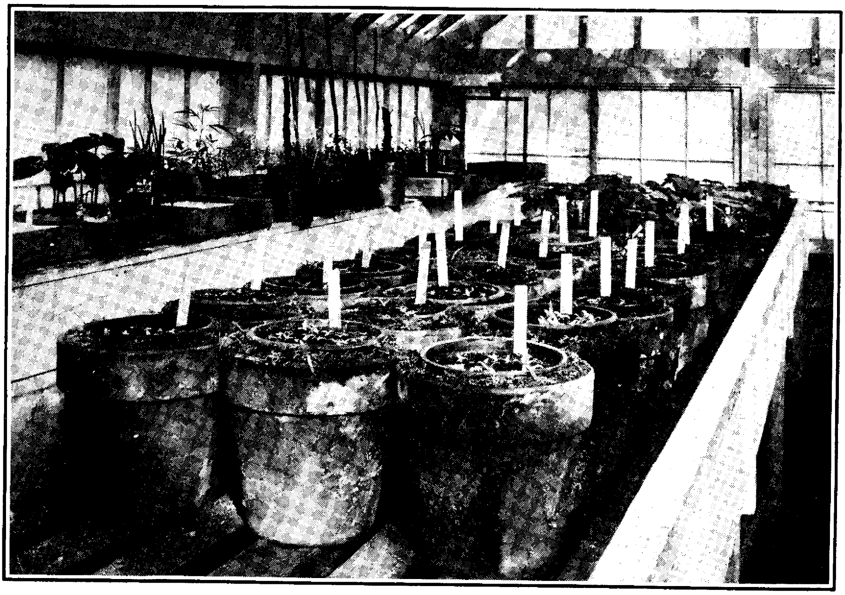

FIG. 1.—PINEAPPLE SEEDLINGS IN DOUBLE POTS.

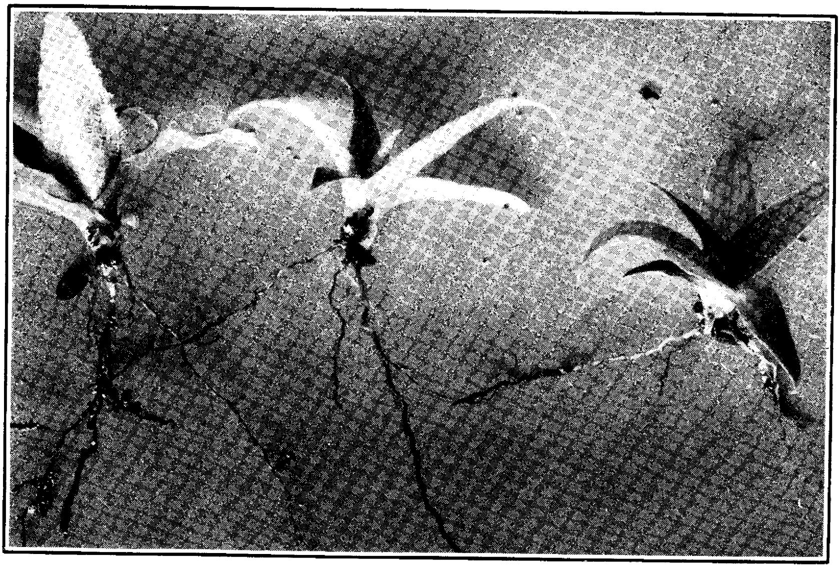

FIG. 2.—PINEAPPLE SEEDLINGS, SHOWING ROOT SYSTEM.

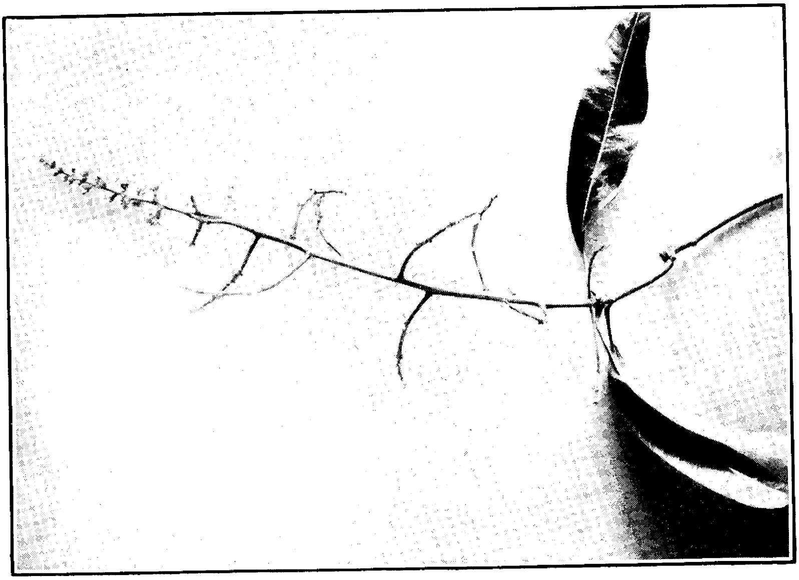

FIG. 2.—SAME FLOWER CLUSTER PREPARED FOR ARTIFICIAL POLLINATION.

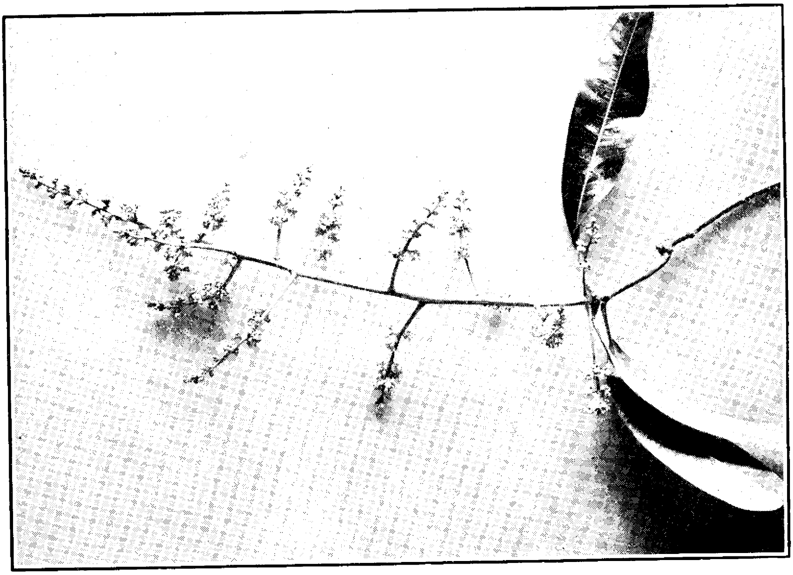

FIG. 1.—FLOWER CLUSTER OF MANGO.

several weeks and of successfully shipping them long distances by mail. Over 1,000 seeds were sent in one shipment to Florida, and were reported to have arrived in excellent condition. The method used consisted in packing perfectly fresh seeds in sphagnum moss very slightly moistened and wrapped in waxed paper surrounded by corrugated strawboard and an outer wrapper. It is important to avoid excessive moisture, as this hastens the germination of the seeds. In the shipping experiments water was added equal to half of the weight of the dry moss.

On February 3, 1916, the attention of the station was called to an apparently serious disease of the litchi. Careful investigations showed this to be due to the work of very large numbers of mites which produced galls and caused the leaves to become much distorted and covered on their under surface with a brown, woolly growth composed of trichomes, or plant hairs. Because of the similarity of this injury to the erinose disease of the grape, which is caused by another mite of the same genus, the name litchi erinose has been applied to the malady. The mite proved to be an undescribed species of Eriophyes. Experiments were undertaken immediately to determine methods for the control of the pest, and an efficient remedy has been found in spraying the tree several times with nicotin sulphate and whale-oil soap, mixed according to the following formula: Ten ounces of nicotin sulphate, 1¾ pounds of whale-oil soap, and 50 gallons of water.

Before spraying it is advisable to remove the leaves that have been most seriously injured, since these are of little use to the tree. In most cases these leaves do not represent a very large proportion of the foliage. This procedure aids in getting the mites rapidly under control, since it is difficult to make the spray enter every deep gall and penetrate the woolly covering of the leaf. If the mites are known to be present, spraying early in the season will probably keep them well in check without the necessity of removing any leaves. It is worthy of note in this connection that the longan tree, a related species, has not been found infested with this mite, although surrounded by infested litchi trees.

A survey of the city of Honolulu showed the erinose disease to be prevalent on litchi trees in several parts of Nuuanu Valley and the Kalihi district, but it was not found at Moanalua or in any other portions of the city.

CROSS-POLLINATION OF THE AVOCADO.

Owing to the illness of V. S. Holt, assistant horticulturist, during the season when the avocados were in flower, progress was somewhat delayed on this project. Prior to Mr. Holt's return to the work, James Cowan devoted some time to this project. Studies have been made of the flower, the maturation of pollen, and the technique of hand pollination, including emasculation and thinning the flowers. The proper thinning of flowers was found to be a very important factor in success, as improper thinning causes many of the hand-pollinated flowers to fall. It was not easy at first to effect cross-fertilizations, but before the end of the season a considerable number of apparent crosses were made successfully.

CROSS-POLLINATION OF THE MANGO.

The location of this work for the present year was shifted from the station experimental orchards to Moanalua Gardens, near Honolulu, because of the total failure of the station trees to flower this season after the heavy crop of July and August, 1915. Through the courtesy of the management of the Moanalua Gardens, it was possible to carry on the work there but under greater difficulties because of the distance from the station and the necessity of frequently visiting the trees before and after pollination.

The first phase of the work was the determination of a suitable technique for the pollination of the mango, and the second, the origination if possible of new varieties combining desirable characters now found in different varieties, as, for example, the high color of the Scott with the flavor and texture of the Pirie. It is felt that much has been accomplished in relation to the development of an efficient technique in so far as the results can be judged by the setting of the fruits, a considerable number of which were nearly mature June 30, 1916, being apparently the result of cross-pollination. These crosses include the varieties Scott, Pirie, Kavasji-Patel (Cowasjee-Patel), Alphonse, Paheri, Java, and a new unnamed sort.

On the mango there may be several hundred flowers in a single cluster which is able to mature only a few fruits (Pl. II, fig. 1). In cross-pollinating, it is necessary to select a few of the best flowers and to cut out the others to prevent their setting fruit. This makes it possible to segregate the selected flowers and protect them from chance fecundation by covering the cluster with a paper bag. Frequently the best flowers are found on the very short branchings near the outer end of the central axis. When such is the case, the flowers are removed from the larger side branches (see Pl. II, fig. 2), but these side branches must not themselves be cut off or the whole cluster may fail. The flowers at the end of the cluster are not disturbed. In carrying on this pollination work, flowers are prepared the day before transfer of pollen is made. After the flowers have been emasculated and any others that might pollinate them have been removed, the whole cluster is covered with a large paper bag which must be removed for pollination and be replaced immediately. Later flowers on the cluster may be operated upon in the same manner.

MISCELLANEOUS BREEDING WORK.

The work in papaya breeding has proceeded along the lines indicated in earlier reports and in a bulletin of the station.[1] There are at the present time no specially important developments to be recorded. A number of new plantings have been made from seeds collected from the cross-pollination of different forms and some of these plants are now coming into fruit. The chief work at the present time includes the hand-pollinating of elongata forms for the purpose of securing a strain which will produce this type of fruit with the greatest possible uniformity, the crossing of certain forms to secure further data relating to the determination of sex and the combining of desired characters.

The 72 seedlings, believed to have resulted from the attempted hybridization of the Chinese wood-oil nut (*Aleurites fordii*) with the Hawaiian kukui nut (*A. moluccana*) and referred to in the annual report for 1915, have been transplanted to the Tantalus substation where both of the parent species succeed better than at the lower altitudes. The seedlings rather closely resemble the female parent in most cases, but present some noticeable variations which are thought to be due to hybridization.

MISCELLANEOUS FRUITS.

The general variety and cultural tests with tropical and subtropical fruits have been continued, including the establishing of plantings of a large number of species and varieties as a basis for any further experimental work which it may seem advisable to undertake. The citrus orchards at the central station are in better condition than they have been for some years past, owing in part to favorable weather conditions with frequent rains which have relieved the difficulty arising from shortage of water. Another factor which contributes to the present condition of the orchards is the better control of insect pests than in the earlier years. The Mediterranean fruit fly, however, continues to be a serious pest in case of oranges and grapefruit, limes being less injured than these and lemons suffering least of all the citrus fruits. The Villa Franca and the Eureka lemons have borne heavily in the main orchards, and on Tantalus, at an elevation of about 1,000 feet, where a few trees of Genoa lemons have been planted, the results are very satisfactory. It would seem that a larger proportion of the lemons consumed in Hawaii might be grown here.

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[1] Hawaii Sta. Bul. 32 (1914).

The mango crop for the summer of 1916 in the station orchards is almost a complete failure, as is the case with mangoes in most parts of Honolulu. This is probably due in part to the continuous heavy rains during the flowering season and also in part to the very heavy crop during the summer of 1915. It is probable that a severe thinning of the fruits in the early part of 1915 would have resulted in a finer quality of fruit in 1915 and an increase in production in 1916.

The avocado orchard, which is on rather heavy soil underlaid in places by rock, suffered from the excessive rains during the winter season, but the trees which escaped this injury set a fair crop in 1916.

Feijoa sellowiana has made two attempts at fruiting, one during the past year, but has failed to bring fruit to maturity. This new fruit, commonly known as the pineapple-guava or feijoa, is now attracting much attention among the growers of subtropical fruits in California and Florida. It is indigenous to western Paraguay, southern Brazil, Uruguay, and Argentina, where its fruits are highly esteemed. The fruit has the appearance of a small guava and somewhat resembles the pineapple in flavor. These characteristics have given rise to the name pineapple-guava. The two trees in the station collection have made good growth and appear to be in a thiriving condition, but both have been slow in coming into bearing, and, as stated above, neither has yet matured a crop, although the larger of the two was well loaded with fruits which grew to about three-quarters the normal size before falling.

Some experiments in grape culture have been undertaken on a cooperative basis with a grower at Wahiawa on the island of Oahu. The vines planted are of the Hawaiian strain of the Isabella variety which has given best results in these islands. If other varieties are grown they will be grafted on these stocks. The experiments have included the trial of different methods of preparation of the soil, the use of fertilizers, and the control of the Japanese beetle (*Adoretus umbrosus*). Other experiments may be developed as the vineyard progresses.

Preparations have been made by F. G. Krauss at the Haiku substation for planting several acres of gulch land to the more important tropical and subtropical fruits, as avocados, mangoes, oranges, limes, lemons, grapefruit, grapes, etc.

MISCELLANEOUS PLANTINGS AT TANTALUS SUBSTATION.

For over 20 years miscellaneous plantings have been made in the vicinity of what is now the Tantalus substation. Some of the early plantings were made before the establishment of the experiment station and have continued under observation until the present time.

From time to time since the establishment of this experiment station, miscellaneous plantings have been made, mostly of material which was thought to require an elevation higher than that of the central station in Honolulu, which is only a little over 100 feet above sea level. Most of the plantings were tree stock, which requires a rather long period for maturity. It was thought, however, that for purposes of record the available notes of previous years and the current notes should be assembled and published. The notes on a number of species are appended.

Two loquat trees (*Eriobotrya japonica*) were planted in January, 1907. The trees were secured from the California Nursery Co., Niles, Cal., and were of the Giant and Victor varieties. The trees have made healthy and vigorous growth and have borne regularly for several years. The fruit of the variety Giant is large, bright orange in color, and is produced in large clusters. The flavor is considered very good and the fruit is considered adapted for use in sauces, jellies, preserves, pies, etc., as well as for eating uncooked. The fruit of the Victor is smaller and lighter in color. When eaten fresh the flavor is said to resemble somewhat that of cherries. The tree is more vigorous and a heavier cropper than the Giant.

Two lots of camphor trees (*Cinnamomum camphora*) have been under observation, one planted in 1894, the other in 1908. The older trees are much larger than the later plantings and are sufficiently developed for a test of their camphor content. The trees of the later planting were from 8 to 12 feet in height on April 15, 1916, with a spread of 6 to 7 feet. The trees appear healthy, vigorous, and without insect or fungus pests. They are of the variety which yields the Formosan camphor. No attempt has been made to determine the commercial value of these trees for Hawaiian conditions.

A small group of trees of *Macadamia ternifolia* is growing at the substation, the trees having been planted shortly prior to 1893. The trees are vigorous, considering their crowded condition, and some bear fruit quite regularly, indicating their value if properly cultivated and fertilized. The nut, which is known as Australian nut, is rich, highly flavored, and contains more than 66 per cent fat. The composition of the nut is given in the report of the station for 1914. The most serious obstacle to the commercial importance of this nut is its extremely hard shell.

REPORT OF THE CHEMICAL DIVISION.

By Maxwell O. Johnson.

During the past year the work of the chemical department has been mainly on problems of soil research, especially those of pineapple soils. The project on legumes as green manures was completed and the project on the acidity of Hawaiian soils continued with some modifications as compared with previous years. The hydrocyanic acid in cassava roots was determined by a new method devised in this laboratory for the determination of this acid in very small amounts. Such soil, fertilizer, feed, and other analyses in connection with the general work of the station as were possible with the reduced staff were performed during the year.

CHEMICAL STUDIES OF THE COMPARATIVE EFFICIENCY OF VARIOUS LEGUMES AS GREEN MANURES IN HAWAII.

During the past fiscal year Miss Alice R. Thompson, assistant chemist, completed the pot experiments comparing the relative efficiency of the various legumes as green manure crops and the results have been submitted for publication. These experiments were described in the annual report for 1915.

Twenty-two varieties of legumes were grown on two Hawaiian soils of different types. Three crops were matured, using four pots for each trial of each variety. The plants were removed at maturity and weighed and the amount of nitrogen in them determined. The nitrogen was determined in the soils before planting and after removing the crop, and it was shown that the soils had lost no nitrogen and had usually made a slight gain, owing probably to decayed roots and nodules. The amounts of nitrogen contained in the various legumes were thus clearly gained by bacterial assimilation of atmospheric nitrogen. When, however, the plants were turned under with the soil and allowed to weather for several weeks, leaching of the rapidly formed nitrates took place, and when the soil was analyzed the gain in nitrogen in many cases was less than it should have been according to the amount of nitrogen turned under. This is of interest, as in most previous experiments with legumes the gain in nitrogen has been calculated by an analysis of the soil after a crop of legumes has been turned under. It is thought that the first method (that of determining the nitrogen in the crop removed and showing that the soil has suffered no loss in nitrogen, or deducting the loss if there should be any) gives results by which the legumes can be better compared with other nitrogenous fertilizers, as these fertilizers also suffer loss by leaching in the soil. These results would indicate that unless a planting is made soon after turning under a green manure crop there may be a considerable loss of quickly available nitrogen.

LIMING AND SOIL ACIDITY.

It is remarkable that, in spite of the great excess of bases found by analysis in Hawaiian soils, many of these soils should show a high degree of acidity when tested by the Veitch and other methods. In view of this fact and the increasing evidence of the benefits of liming in the States, a thorough investigation is being made of the character of the acidity of Hawaiian soils and the effects of lime on their properties. Large quantities of soils from three different islands (Hawaii, Oahu, and Kauai) have been secured, and the results of tests with these, it is hoped, will be of fairly general application in the islands. On the assumption that in whatever form lime is applied the carbonate and bicarbonate will result, an investigation is being made of the reaction of Hawaiian soils to calcium bicarbonate under various conditions, and the results promise to be of considerable value.

THE KAUAI PINEAPPLE WILT.

The "Kauai wilt" of pineapples is a very serious trouble, affecting the success of many homesteaders on the island of Kauai, especially in the Kapaa district. As preliminary tests of soil samples secured from this section in connection with a general field trip by the chemist showed a very small amount of lime in the soil, with a high degree of acidity, and about half as much lime in the ash of the wilting plants as in that of the healthy ones, it was therefore thought that acidity might have some connection with the wilt. A special trip was made to the pineapple district of Kauai and a large number of soil samples secured. As one result of the analyses made, a successful correlation was worked out between the wilt and the light-yellow soils, which have been derived from lavas acted upon by steam and sulphuric acid vapor near centers of former lateral crater activity. The acidity of the samples collected corresponded closely with the field notes on the wilt. Pot and field experiments with different forms and amounts of lime are being made to determine the effect of liming.

THE YELLOWING OF PINEAPPLES ON MANGANESE SOIL.

Considerable areas in the Wahiawa, Kunia, and other pineapple districts of the island of Oahu contain large amounts of manganese. The pineapple plants on these black manganese soils are affected very seriously, turning yellow and producing little fruit, which is of inferior quality. These manganese soils and their effect on the pineapple plant have been investigated thoroughly by this station in former years and the results published.[1] In these publications the yellowing is attributed to some indirect action of the manganese in the soil, as "a modification in the osmotic absorption of lime and magnesia." Up to the beginning of 1916 the only treatment that has been at all successful has been the application of large quantities of stable manure. This method, however, is very expensive, and the supply of available manure is limited.

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[1] Hawaii Sta. Buls. 26 (1912) and 28 (1912), Press Bul. 23.

It appeared to the present chemist of the station that the pineapple plants were suffering from an insufficient supply of iron, a small amount of which is considered necessary for the proper functioning of the chlorophyll. Field trials confirmed this hypothesis, since yellow and dying plants brushed with a solution of iron sulphate rapidly became green and healthy and began a vigorous growth, which has continued up to the present time (June 30, 1916). Numerous field experiments have been made on large areas of yellow plants which were sprayed with a solution of iron sulphate and in every case the treatment has proved successful. The best conditions for application, the most suitable strength of solution, the optimum number of sprayings, etc., are being worked out, but already it is apparent that this treatment will be very profitable to the growers, as excellent crops are ripening on manganese soil on which approximately $2.50 an acre for four sprayings has been spent.

HYDROCYANIC ACID IN CASSAVA.

The roots of the cassava or manioc (*Manihot utilissima*) contain the very poisonous hydrocyanic acid (prussic acid). Owing to the increasing cultivation of this plant in Hawaii for the preparation of starch and as a cattle and hog feed, determinations of this hydrocyanic acid were made. Previous methods for the determination of small quantities of this acid proving unsatisfactory the chemist devised a convenient and accurate method, which has since been published.[1] Some determinations of the hydrocyanic acid in cassava are of interest. Unfortunately, the varieties used could not be classified except under their vague common names of "bitter" and "sweet."

Hydrocyanic acid content of cassava.

No.	Kind.	Source.	Age.	Character of soil.	Diameter of root.	Part of plants.	Hydrocyanic acid.
			Mos.		*Inches.*		*Per ct.*
1	Sweet	Station	18	Poor heavy clay	1	Whole roots	0.006
2-A	do	do	6	Good light clay.	¾	do	.025
2-B	do	do	6	do	¾	Peel of roots	.042
2-C	do	do	6	do	¾	Peeled roots	.021
3-A	Bitter	do	6	do	¾	Whole roots	.008
3-B	do	do	6	do	¾	Peel of roots	.015
3-C	do	do	6	do	¾	Peeled roots	.007
4-A	do	do	24	do	5	Whole roots	.013
4-B	do	do	24	do	5	Peel of roots	.025
4-C	do	do	24	do	5	Peeled roots	.007
5	Sweet yellow	Waialua, Oahu		do	1½	Whole roots	.006
6	Bitter	Kauai	9	do	1	do	.014
7	do					Waste (from whole roots used for starch manufacture).	.003
8	do					Waste (from peeled roots used for starch manufacture).	.0008

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[1] Jour. Amer. Chem. Soc., 38 (1916), No. 6, pp. 1230–1235.

From the results obtained it would appear that cassava waste is perfectly safe for use as a hog feed, if, as is usually the case, it is boiled before feeding. Moore[1] estimates 0.008 per cent or more of hydrocyanic acid as dangerous in feeding the fresh root. The chemical division would caution against the use of cassava for feed unless the finely divided roots are thoroughly boiled with two or three changes of water.

THE EDIBLE CANNA.

The edible canna (*Canna edulis*), known also as the "Queensland arrowroot" and "tous-les-mois," appears to be well suited to Hawaiian conditions. Analyses were made of samples submitted by J. B. Thompson, superintendent of the Glenwood substation, Hawaii. Two sizes of canna rootstocks were analyzed. No. 1 refers to the small rootstocks about 2 inches long and No. 2 to rootstocks 5 or 6 inches in length. The results are figured on both the fresh and the water-free basis. The results given for the fresh rootstocks are most interesting. They show little difference in the ash, fiber, fat, and protein for the small and large rootstocks, but a remarkable increase in the nitrogen-free extract in the larger rootstocks. The following table gives the results of the analyses:

Analysis of the edible canna.

Constituent.	Fresh basis.		Water-free basis.	
	No. 1.	No. 2.	No. 1.	No. 2.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Water	81.58	65.86	....	....
Total solids	18.42	34.14	100	100
Ash	.81	.81	4.39	2.37
Crude fiber	.54	.64	2.93	1.88
Fat (ether extract)	.13	.15	.71	.44
Protein	1.37	1.20	7.45	3.52
Nitrogen-free extract (starch, sugar, gums)	15.57	31.34	84.52	91.79

REPORT OF THE DIVISION OF PLANT PATHOLOGY.

By C. W. Carpenter.

The division of plant pathology of the station was established June 1, 1916, with the transfer of the present pathologist from the Bureau of Plant Industry, United States Department of Agriculture. Previous to June 1, the investigations of diseases of plants at this station had been limited to such studies as could be made by the members of the staff incidentally along with their regular lines of work. It had become more and more evident, however, that the diseases of the economic plants of the islands demanded more adequate attention than had been given them.

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[1] U. S. Dept. Agr., Bur. Chem. Bul. 106 (1907), p. 16.

The pathological laboratory has been fairly well equipped and is being brought into working order as rapidly as possible. Arrangements have been made for the installation of an herbarium case in which pathological specimens will be deposited as they become available by collection and exchange.

The most important diseases at present calling for attention are late blight of Irish potato, late blight of celery, anthracnose of avocado and mango, taro rot, and banana and pineapple wilt. Other plant diseases have been observed as follows: Leaf spot and fruit rot of papaya; leaf spot, stem blight, and fruit rot of guava; leaf blight and pod blight of Lima bean and string bean; common scab of Irish potato and also a wilt disease of this host which has been confused with Phytophthora blight; and cabbage soft rot. Leaf injuries probably of fungus origin have been noted on the following hosts: Lemon, orange, fig, peach, poha, coffee, carrot, sorghum, loquat, Java plum, corn, rutabaga, sweet potato, and pineapple. Knotting and dwarfing of young corn plants appear to be serious in certain localities. Specimens of stem blight of mammee apple (*Mammea americana*) similar to that on guava have been collected.

REPORT OF THE AGRONOMY DIVISION.

By C. A. Sahr.

During the year new projects on cassava and fiber plants were inaugurated. The project on cassava includes test of varieties for the production of forage and starch, the determination of best cultural methods, and a study of methods for the utilization of cassava waste. The project on fiber investigations has for its object the determination of yield and quality of different fiber plants, especially sisal (*Agave sisalana*) and sunn hemp (*Crotalaria juncea*).

AQUATIC CROPS.

The work with rice and taro in the vicinity of Waiau, Oahu, is progressing favorably. Checks have been made upon average yields obtained from the 1915 spring and fall crops from the plat designed to serve for the test of aeration of soil for rice. Owing to excessive rains and high winds the 1916 spring crop of the nonaerated plat fell 51 per cent below the yield of the same in 1915. In the aeration soil test for the spring crop of 1916 the nonaerated plat outyielded the aeration plat by 18.7 per cent, the increase favoring nonaeration being 490 pounds of rice paddy.

The test of aeration of soil for taro was begun in the middle of August, 1915. The fertilizer test with taro was inaugurated at the same time, and it was expected that the plats would be harvested during the first week in July, 1916. Further work with aquatic crops has been commenced in cooperation with Jonathan Aiau at Waialua.

POTATOES.

The work with potatoes for the year at the central station was limited to the planting of three varieties to obtain material for pathological investigations. The manured portion of the plat was divided into three sections for further tests with Bordeaux mixture and lime sulphur spray for the control of fungus diseases. In a variety test at the Tantalus substation (elevation 1,000 feet), the Early Rose outyielded the Burbank and the American Wonder. In a culinary test of these varieties, the Burbank, although exceeded in size by the American Wonder and the Early Rose, proved superior in mealiness and flavor.

LEGUMES.

Four new varieties of velvet beans were received from the Office of Forage Crop Investigations, United States Department of Agriculture, during April, 1915, and were grown in the variety test plats with one variety from Porto Rico (supposed to be *Stizolobium capitatum*) and seven varieties under test by this station for several years. The stands obtained from the four new varieties were too uneven for reliable yield data. Sufficient seed was obtained for a second planting.

Another legume of unusual promise as a green manure or forage crop has been found in the muth bean (*Phaseolus aconitifolius*), seed of which was received from the Bureau of Plant Industry. As with kulthi (*Dolichos biflorus*) the water requirement of the muth bean is much lower than that of most other leguminous forage crops. The growth is at first erect but soon becomes prostrate, forming a dense mat upon the soil. Calculations from trial cuttings of muth bean grown between rows of pineapples represent average yields of about 15 tons green matter per acre for a four months' period of growth. (See Pl. III, fig. 1.)

Crotalaria candicans (S. P. I. No. 28606), of which mention under the name *C. madurensis* was made in the annual report of this division for 1915, has given considerable promise as a leguminous shrub for shading in coffee nurseries. Although somewhat checked by drought and aphis attacks in the summer of 1915, the plants failed to show material effect of damage from either of these sources of injury.

With the early fall rains considerable damage from scale was noted on the main stems and lower branches. This trouble was effectively treated with a proprietary oil spray especially prepared for the San José scale. The plants came to full bloom during January, 1916, the pods maturing in early March. A plat 8 by 8 feet having 11 plants produced 3½ pounds of seed.

Trials with *Desmodium hirtum* for several years failed to produce results of consequence. Growing the plants in shade was suggested, and a further trial was made on a plat prepared not 10 feet away from the trunk of a flourishing young algaroba tree. The growth made by the shaded plat of this legume during a period of 6 months is nearly equal to that made by another plat in the open during 15 months.

Of the true clovers (*Trifolium pratense*) planted in the forage plant garden February 27, 1915, cuttings of the red clover plats were made on January 5, 1916. The average yields of green forage for these clovers are as follows: Red clover from Switzerland (S. P. I. No. 37939), 8.55 tons; ordinary red clover (F. C. I. No. 1472), 8.45 tons; Swiss Rummellee clover or apitrefle (S. P. I. No. 37937), 2.1 tons; and red clover from Switzerland (S. P. I. No. 37938), 1.8 tons.

The clover plants have flourished in the past season of unusual coolness and humidity during the spring of 1916, and the next cutting will be made for seed in the latter part of July, 1916. A cutting of the alsike clover made January 20, 1916, represents a yield of 6.15 tons per acre. Further cutting of this stand also awaits proper maturation of seed. Of the white clovers, ordinary white (S. P. I. No. 34930) made appreciably more growth than did wild white (S. P. I. No. 38579) and Ladino white (F. C. I. No. 1482). A stand produced from *Trifolium striatum* (F. C. I. No. 1450) succumbed to drought in the summer of 1915, while *T. dubium*, replanted on April 17, 1915, produced a good stand and was maturing seed in July, 1916.

SMALL GRAINS.

A test of small grains for yields of grain and forage was begun December 15, the experiment including five varieties of winter rye, two varieties of oats, and one variety of winter barley. As in previous tests the ryes made the best growth at the start, but to date only the Mexican winter rye (Pl. IV, fig. 1) has headed out, and the stand is so sparse as to indicate exceedingly unsatisfactory yields of both grain and forage. The oats stands of both the manured and check plats were harvested June 5, Fulghum yielding 70.75 pounds forage and 2 pounds 13½ ounces grain for the manured plat and 59 pounds forage and 2 pounds 5½ ounces grain for the check plat (Pl. IV, fig. 2) while Red Rustproof yielded 112.5 pounds forage and 2

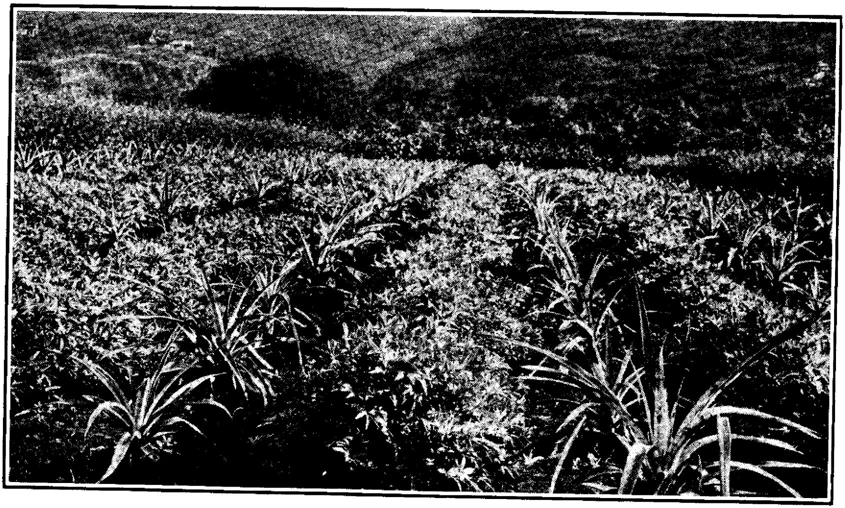

FIG. 1.—PINEAPPLES INTERPLANTED WITH MUTH BEANS FOR GREEN MANURE.

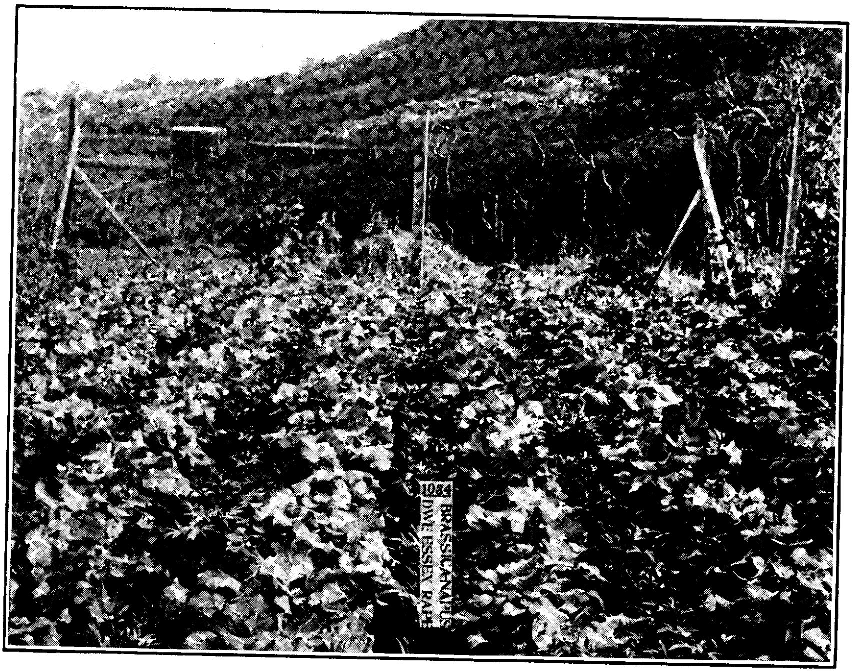

FIG. 2.—DWARF ESSEX RAPE INTERPLANTED WITH MUTH BEANS.

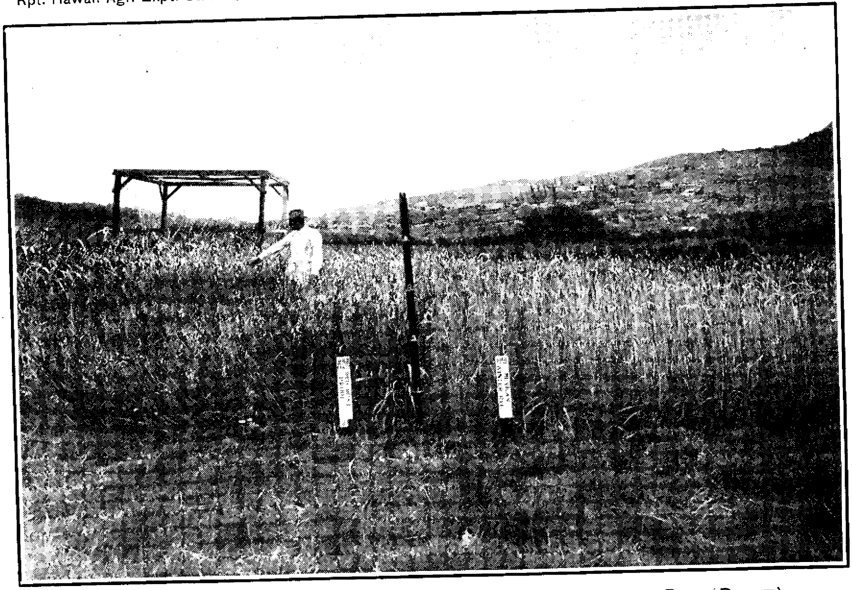

FIG. 1.—RED RUSTPROOF OATS (LEFT) AND MEXICAN WINTER RYE (RIGHT).

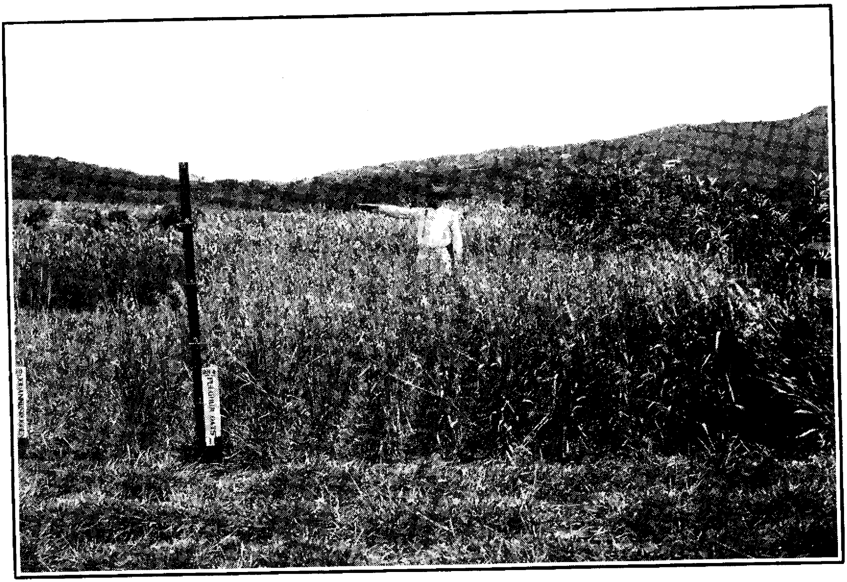

FIG. 2.—JOHANNES WINTER RYE (LEFT) AND FULGHUM OATS (RIGHT).

pounds 5½ ounces grain for the manured plat, and 94 pounds forage and 3 pounds 13 ounces grain for the check plat (Pl. IV, fig. 1), indicating yields of from 13 to 22 bushels of grain per acre. The stand of winter barley has failed to head out to date.

A second planting, including five varieties each of oats, barley, and rye, and three varieties of wheat, was made March 28. Of the oats, Fulghum, Swedish Select, and Sixty Day had headed out to some extent on June 5, Fulghum taking the lead. Of the barley, only the Smyrna variety had headed out by June 5. A yellow wilted area across the center of the barley plats was found upon examination to be due to an attack of aphis. Owing to the moist and cool conditions prevailing during the spring the ryes and wheats, with the exception of the winter varieties, are expected to produce good results. Duplicates of the cereal tests described above are being made at Waimea, Hawaii, and at Makawao and Haiku, Maui, the tests in the first two districts named being made at an altitude ranging from 2,500 to 3,200 feet.

SORGHUMS.

Owing to the very limited area on which corn can be profitably raised in the Territory, attention has been given to the production of grain sorghums to supplement corn. The results of a test for yields of grain and forage with kafir corn, milo maize, and feterita in comparison with Sugar Drip sorghum, sown April 19, 1915, are given below:

Results of a comparative test with sorghums.

Type of sorghum.	Date of harvest.	Plat yields.		Acre yields.		Number of days to mature.
		Forage.	Grain.	Forage.	Grain.	
		Pounds.	*Pounds.*	*Tons.*	*Pounds.*	
Kafir corn	Aug. 5	993	5½	6	66.5	107
Milo maize	Aug. 2	748	36¼	4.52	436	104
Feterita	do	1,100	19⅛	6.65	235	104
Sugar Drip	Aug. 5	1,863	57	11.27	689	107

The low yields of grain and forage from kafir corn substantiate the statement made in the 1915 annual report that yields from this crop are very adversely affected by drought. It should be stated here, however, that the extremely low yields of grain recorded for the kafir corn in the above test are also due to harvesting before the stand obtained uniform maturity, about 10 days more being required with kafir corn than with Sugar Drip sorghum.

In the 1916 test of grain sorghum, Manchu kaoliang, dwarf milo, and dwarf kafir have been added to the number included in the 1915 test. These were sown April 15 under the most equable conditions obtainable. The first heads were noticeable in the Manchu kaoliang stand on June 1, in the feterita on June 3, and in the milo maize on June 7. The fact that kafir corn, milo maize, and kaoliang have been listed under grains in the San Francisco and Los Angeles Produce Exchange for some time past suggests the importance of the production of these crops in Hawaii, since heavy importations of grains are at present necessary.

A new long-period test for yields of forage was begun in August, 1915, and excellent stands of nonsaccharin sorghum No. 309 and of Japanese cane were obtained, the plantings being made July 17 in field N, west of the administration building. The plat of No. 309 sorghum consists of 33 rows 4 feet apart, each row containing 36 plants 2 feet apart in the row. The stand of Japanese cane was planted in 26 rows, 77 feet long and 5 feet apart, of which 13 were propagated by division of roots and the remaining half by cuttings of the canes. The stand was cut for the first time for yield of forage December 29, the estimated acre yield of the stand produced from cuttings totaling 2 tons more than the yield of the stand produced by division of roots.

GRASSES.

Cuttings of two new grasses, Napier grass (*Pennisetum purpureum*) and Cayenne grass (S. P. I. No. 38946), were received from the Bureau of Plant Industry December 24 and planted on December 29. A good stand of Napier grass was obtained, but only a single plant of Cayenne grass. The first-named produced flourishing heads throughout April, but owing to ravages by birds no seed was obtained. A large assortment of grass seeds containing a few varieties previously introduced was also received from the Bureau of Plant Industry in April, and is being held for planting when the autumn rains commence.

Demonstration plats, each 96 by 19½ feet, were planted in field N to Wilder grass (*Andropogon nodosum*), Australian blue grass (*A. sericeus*), fuzzy top (*A. saccharoides*), Natal redtop (*Tricholæna rosea*), and a triangular plat, 97 by 56 by 113 feet, was sown to Giant Bermuda grass. (See Pl. V, fig. 1.) These grass plats represent the five best drought-resistant pasture grasses for low and medium elevations. (See Pl. V, fig. 2.)

Of the grass plats in the grass garden planted in the fall of 1913, Mitchell grass (*Astrebla triticoides*), side oats grama (*Bouteloua curtipendula*), tall fescue (*Festuca elatior*), American buffalo grass (*Bulbilis dactyloides*), *Bromus unioloides*, *B. erectus*, *Paspalum notatum*, *P. nodosum*, and *P. virgatum* have continued to thrive, although severly checked during seasons of drought. Other grasses sown at the same time and sharing the same conditions of growth, while unthrifty, still persist in their original plats. Of these, a single plat of meadow foxtail (*Alopecurus pratensis*) produced heads in May, and *Paspalum compressum* bloomed in April. Slender wheat grass (*Agropyron tenerum*), *Phalaris bulbosa*, *Poa arachnifera*, and *Bromus sericeus* furnished considerable herbage, but so far have failed to bloom.

NUT GRASS CONTROL.

As in the previous years, work on control of Japanese nut grass has proved that spraying with arsenite of soda is the most effective means of control if the spray is applied when the grass is in full bloom. Plowing with a disk plow is effective if done at intervals of four or five weeks during exceedingly dry periods. Quantities of tubers found on the surface of the soil following effective plowing and raked together after weathering for four weeks, when again planted in boxes, failed to start new growth after a reasonable period.

MISCELLANEOUS CROPS.

Cotton.—Representative stands of Egyptian, Sea Island, Columbia (upland), and Caravonica "wool" cotton have been maintained for demonstration purposes and to supply select seed of each variety.

Corn.—A repetition of the 1914 fertilizer and rotation test with Reid's Yellow Dent corn was commenced in November, 1915. The mechanical condition and moisture content of soil during the life of the stand were favorable, but after five weeks of growth the stand was materially affected by the leaf hopper (*Peregrinus maidis*), the yield of grain being so reduced as to furnish no reliable data.

Rape.—Tests with rape in previous years have generally been failures owing to the loss of the crop through drought and aphis attacks. A stand of Dwarf Essex rape obtained from a planting made May 1 is shown in Plate III, figure 2, made 32 days after sowing. The second rows on each side of the stake, cut for estimating the approximate yields of forage per acre, averaged about 11 tons produced in 50 days.

SEED DISTRIBUTION.

As in previous years the demand for seed by farmers and homesteaders has been large, chiefly for seed of pasture grasses and soiling crops. Numerous requests for cuttings of forage grasses which do not produce seed readily were filled by the division. Among these should be mentioned especially the Giant Bermuda grass, which is proving very promising for pasture and hay.

REPORT OF THE EXTENSION DIVISION.

By F. G. Krauss.

GENERAL ASPECTS OF THE WORK.

The extension division during the past year has given increased attention to the purely extension phases of the work. The writer has made seven official trips during the year, all the principal islands having been visited and numerous cooperative connections established. Nearly all the members of the entire scientific staff of the experiment station have made one or more trips to the various islands where it was possible for them to give valuable assistance along extension lines in connection with their principal lines of inquiry and investigation. Much of the extension work with farmers has necessarily been done through correspondence, nearly 800 letters having been received and answered during the year, in addition to at least an equal number handled at the experiment station at Honolulu. Fully 200 persons have visited and inspected the central demonstration farm on Maui during the past year. About 20 meetings of farmers have been attended by the station staff where part was taken in speaking and in discussions. A number of prominent agriculturists and educators have been invited to address farmers' assemblages held under the auspices of the extension division.

In addition to extension work, the division has given considerable attention to two related phases of the work. The extraordinarily wide diversity in soil, rainfall, and exposure to winds makes it impossible to lay down hard and fast rules regarding the details of the best agricultural practices upon a given farm in any particular section of the islands. Two localities well within sight of each other may require an entirely different set of crops and cropping systems. This condition of affairs calls for the working out of the best practices in each particular locality. This is being accomplished by means of cooperative field tests of different methods of crop production and demonstrations on the farms of the best farmers available and also on specially equipped demonstration farms, five of which have been established in different parts of the islands under the direct management of the extension division.

The second related phase of extension work to which attention has been given has been the organization of the farmers for their mutual benefit for business and social purposes, and especially for marketing to best advantage the products of their farms. This branch of the work, although but recently instituted, already has resulted in the organization of several important farmers' associations which have assisted in developing new markets for farm produce as well as in helping to start several new and promising cooperative agricultural enterprises which, it is believed, will prove of material benefit to the small farmer. E. C. Moore has had immediate charge of carrying out this work of organization.

EXTENSION OF NEW CROPS AND IMPROVED FARM PRACTICES.

Probably the work of most direct benefit to the farmers at large under the present status of the development of diversified agriculture in these islands is the introduction and extension of new crops or improved varieties of established crops and the actual demonstration of improved farm practices. This division has undertaken to establish in various parts of the islands demonstration farms under its immediate control and cooperative experiments with farmers on their own farms. The object has been "teaching by doing" things which hitherto have been merely written and talked about. The demonstration farms at Haiku have had under cultivation during the past year some 60 acres in miscellaneous crops. These crops, the experiment station at Honolulu and the experimental plantings at Haiku have demonstrated, are promising for culture on a commercial scale.

WORK AT THE LOWER DEMONSTRATION FARM AT HAIKU.

This is the principal demonstration farm on the island of Maui. It is situated on the lower and drier section of the homestead tract located in Kuiaha, Pauwela, and Kaupakulua. The farm is typical of an extensive area of potential farming land now devoted to grazing. The units selected for the demonstration work appear well suited to the purpose. While it is at present held in private ownership, it has been suggested that the county of Maui take the land over and make it into a permanent institution. The value of the work undertaken is directly proportionate to the length of time over which such work extends. Cropping systems, based on crop rotation and green-manuring practices, can not demonstrate their value unless carried on over a long period. This can only be assured by State or county ownership.

Thirty-five acres is at present under crops on this farm. Both virgin land and previously cropped land are this year under test to demonstrate their comparative fertility. Careful cost accounts are being kept to determine the comparative expense of clearing land by various methods, such as hand grubbing, blasting, and power clearing. Various "methods of tillage" experiments in connection with the production of the different crops are under way.

The entire area was planted in the spring of 1916 to three established varieties of field corn developed in breeding plats maintained by the writer for several years as a private enterprise. The entire area of corn is being intercropped, as the result of extensive experiments conducted by the writer for a number of years. These crops include the following legumes: Cowpeas, sunn hemp, soy beans, velvet beans, culinary beans (several varieties), sweet potatoes, Irish potatoes, peanuts, and other seed crops for feeding and green-manuring purposes. All are being grown in sufficient quantity to demonstrate their commercial value and also to provide means for obtaining practical figures as to costs of production. Not the least important work at this farm is the working out of satisfactory methods of storage, grading, and marketing of these comparatively new crops.

In addition to the above crops, a large number of comparative tests are being made of new crops to show their adaptability to the prevailing conditions. These crops at present include 18 varieties of cereals, which are being grown in cooperation with the agronomy division of the experiment station, some 40 varieties of grain sorghums and millets, and 10 varieties of root crops, mostly for stock and poultry feeding experiments to be conducted later. Many of these crops are being tested at the direct request of farmers in the neighborhood and throughout the islands.

All the crops at the lower demonstration farm are being grown both with and without fertilizers and with and without green-manuring crops to demonstrate the feasibility of these several practices under existing conditions. Already it has been demonstrated that high-grade fertilizers can be made to double the yield of Irish potatoes, while with field corn the commercial fertilizers have given comparatively little increase. Heavy green manuring, however, more than doubled the yield of corn. Likewise, the crops of corn on virgin soil in this particular locality are fully twice as heavy as on the land previously cropped to corn. From this it would appear that Hawaiian soils generally are lacking in humus, and plans are being made to test this theory in connection with subsequent crops.

An important phase of the cultural work being undertaken at this farm is the selection and improvement of pure strains of farm seeds especially adapted to local conditions. Begun as a private enterprise by the writer in 1912, the work to date has resulted in the establishment of a superior strain of Yellow Dent corn, two superior varieties of Irish potatoes, two new varieties of sweet potatoes, as well as a number of new legumes for green-manuring and stock-feeding purposes.

In the general distribution of seeds and plants inaugurated by this division during the past year there were distributed 6,450 sweet potato cuttings (2 varieties), 825 Irish potato eyes (2 varieties), 150 pounds field corn (3 varieties), 660 root divisions of grasses, 20 pounds grass seed, 87 pounds beans (culinary), and 100 pounds leguminous seeds (for stock-feeding and green-manuring purposes).

A number of the above crops had already become established in the immediate community from a previous limited distribution. Among the most prominent of these is Sudan grass, which in 1913 was represented by a 100-foot test row. It may be safely said that at present at least 100 acres is devoted to this valuable hay and soiling grass in the Haiku district alone. In addition to the stocks indicated above which have been sent out upon request, large quantities have been delivered to persons calling at the farm. In all these distributions the recipients have been requested to report upon the results of their trials. It is believed that such data accumulated from a wide area will in time prove of great value in establishing crop zones.

WORK AT THE UPPER DEMONSTRATION FARM AT HAIKU.

At the upper or central demonstration farm at Haiku, Maui, which constitutes the headquarters of the extension division, the principal lines of work have been with pineapples. A considerable amount of general experimental work supplementing the investigations of the station at Honolulu is being undertaken. A meteorological station, which includes temperature, precipitation, and wind velocity observations, was established in January, 1916, in cooperation with the Weather Bureau. It is planned to extend this phase of the work considerably for the purpose of further correlating crop production with climate, a new line of work recently inaugurated by the United States Weather Bureau at Washington. About 15 acres at this station is now devoted to pineapple experiments and demonstrations. Experiments are now under way in tillage, planting, fertilizing, green manuring, drainage, and determining the relative merits of various types of plants. Five acres are devoted to a cropping and feeding project which has for its purpose the restoration of worn-out pineapple lands, the most important problem which now confronts pineapple growers in Hawaii. Five acres constitute a trial ground for the testing of new crops, seed of which has been furnished largely by the station at Honolulu. At the present time more than 100 grasses, clovers, and other economic crops are being grown in comparative tests. In cooperation with the horticultural division of the station, an experimental fruit-growing project has been developed for the purpose of determining the adaptability of the protected gulch lands for the culture of grapes, citrus, and other tropical fruits. An acre and a half of land has already been cleared and a portion is now being terraced to determine the value of this method of preparing steep hillsides for the cultivation of fruits and other crops. These experiments were undertaken by the station because of the belief on the part of settlers that these heretofore waste lands sheltered from the prevailing heavy winds might be developed into highly productive and profitable areas.

The growing demand for choice home-grown vegetables has led to a series of successive plantings of a large number of the more popular vegetables in order to determine the best season for the different varieties.

EXTENSION WORK IN CONNECTION WITH COUNTY FAIRS.

The extension division has taken the lead in the inauguration of the first Maui County agricultural fair, to be held in November, 1916. Great enthusiasm for it is being shown in every quarter. The sugar plantations and pineapple plantations are cooperating heartily with the so-called small farmer in furthering the common interests of the community. There is every indication that this fair will prove of great value to all concerned, not only for its direct practical value in showing what can be grown, but in bringing the community to a realization of the value of cooperation. This division, through the Glenwood substation on Hawaii, is taking an active part in the furtherance of the second Hawaii County fair, the first fair having proved very successful last year. It is hoped that the county fair idea will spread to each of the other islands and finally result in a great Territorial fair in which all of the counties shall participate.

MAINTENANCE OF FERTILITY OF PINEAPPLE FIELDS.

In the last annual report stress was laid upon the projects planned with a view to working out some rational system of soil management whereby the worn-out pineapple lands could be renovated. The solution of this problem becomes more and more important as the best pineapple areas become used up, as is fast being done. It is as yet too early to predict which of the several methods now being tested will prove most effective in the maintenance of satisfactory yields of pineapples.

The extensive cooperative experiments undertaken with the Haiku Fruit & Packing Co., at Haiku, in which the accumulative renovating power of green-manuring legumes is being tested over a period of five years, is progressing favorably in that the several green-manuring crops planted last fall grew well and were plowed under in the spring of 1916, according to schedule. The same area was again replanted with the exception of the one unit reserved for planting to pineapples. After the entire area has been successively replanted to pineapples and the subsequent crops harvested and weighed valuable data will become available. The experiment and demonstration, however, will not be completed until 1923. This fact is mentioned to indicate the length of time required to conduct an experiment of this nature. Much credit is due the cooperating company for its willingness to undertake an experiment running for so many years.

Another project with the same object was planned with a view to making the land bring in tangible returns during the entire period given over to renovation by leguminous crops. This, it is hoped, will be accomplished by feeding off the crops grown on the land. The resultant gains will contribute to the support of this line of work, which was put into effect in January, 1916. In advance of the report on the completed experiment the preliminary data and estimates are given below in the hope that they may prove suggestive to those interested.

The area under experiment was planted to pineapples in October, 1912. The first crop, averaging 22.5 tons per acre, was harvested between January and November, 1914. The second (first ratoon) crop was harvested during the latter half of 1915, and yielded at the rate of 21 tons per acre. The third (second ratoon) crop (on the divisions still in pineapples) is just beginning to mature. The yield, owing in part to the unfavorable season, will probably fall below 10 tons per acre. The entire area was paddocked off into four equal subdivisions. The first paddock was pastured to four head of mules and one cow per acre during January, February, and March, 1916, and with an average of 10 hogs during April, May, and June, 1916. The area under pasture was covered with a rank growth of weeds and grass as is usual at the end of a cropping period during which weeding has been suspended for a considerable time. The live stock showed preference for the young fruits and buds and even the young leaves of the pineapple plants over the grass and weeds which would ordinarily be classed as fairly good pasturage. At the end of six months the entire herbage excepting the old pineapple stumps had been eaten off, so that the hogs had to be given a small supplementary feeding of sweet potato tops to finish out the six-months period. If an allowance is made at current rate for pasturage of cattle, the land would yield a revenue of $13.80 per acre per annum, without taking account of the remaining half of the year. Much of the value of the organic matter produced on the land is, of course, retained either in the form of stubble or manure, and this is the main object sought. However, the project as now planned calls for the shifting of the stock to the next area as soon as the other section is fed off, while the pastured-off area is immediately plowed and cropped to one of several green-manuring summer legumes. If the season is moist it is planned to plant to field corn intercropped with a legume, which, for the present purpose, is preferably the cowpea or velvet bean, either of which makes excellent feed for growing hogs, especially when supplemented with corn. These crops may, of course, be either pastured off or harvested, cured, and fed separately. From work previously done at the central Haiku farm, where the present project is under way, it is fair to assume that a ton of shelled corn and leguminous seeds can be produced per crop per acre, and that two such crops can be grown per annum. If these estimates are realized in the present project, it will be seen that enough grain should be grown per acre during the last half of the present year to produce from 300 to 400 pounds of pork, live weight, allowing 5 to 6 pounds of grain per pound, live weight. This, with the corn stover and pea vines, will go far toward making the renovation period at least self-supporting.

ORGANIZATION WORK.

One important phase of the extension work has been that of helping the farmers to help themselves through properly organized activities. E. C. Moore, of Haiku, has had immediate charge of this line of extension work of the division. A statute covering the organization of cooperative societies was passed at the last session of the Territorial legislature. A number of cooperative societies have been formed, and the extension division has endeavored to keep in close touch with all the cooperative activities of these organizations and to render all possible assistance to them.

It has been found that the problem of the necessary bookkeeping usually gives considerable difficulty to a newly formed organization of this nature. The immediate object of most of the cooperative organizations has been the more profitable production and marketing of the special crops. The Territorial marketing division, with which the extension division is cooperating, ordinarily handles individual consignments of miscellaneous farm produce, but more closely organized effort is regarded as necessary in connection with the production and marketing of such special crops as pineapples, sugar cane, bananas, and algaroba beans. Some assistance has been rendered various groups of farmers in connection with contracts with the pineapple canneries and the sugar mills for the disposal of their products. During the year a mailing list of farmers has been prepared for the use of the extension division.

COLLABORATION IN EXTENSION WORK.

In order to reach as many farmers as possible on the outlying islands, three farmer collaborators have been engaged to devote a part of their time to the extension work. These are in homesteading sections and on the farm of the best available farmer, and while the collaborator continues to operate his own farm, he also conducts demonstrations in crop production to serve as object lessons to the other farmers of that section. Another duty of the collaborator is to render all possible assistance to the neighboring farmers in the establishment of better markets for their crops and in the development of standard grades of production to meet the demands of the best buyers. The collaborator on Kauai, J. de C. Jerves, has been instrumental in spreading the Madeira sweet potato throughout the islands, where it has proved of exceptional merit.

The collaborator at Hilo, Hawaii, J. E. Gamalielson, has been very active and painstaking in the marketing of dairy and poultry products for the homesteaders in that district. At Kamuela, Hawaii, Mr. John McCoy and his successor, A. L. Arthur, have undertaken demonstrations in the production of crops which can be fed to live stock and thus marketed. The preliminary efforts in raising perishable products in this section were shown to be unprofitable, owing to the distance from markets for such produce and to the lack of suitable transportation facilities.

The extension work of the Glenwood substation at Glenwood, Hawaii, is under the general supervision of the extension division.

REPORT OF THE GLENWOOD SUBSTATION.

By J. B. Thompson.

POLICIES OF THE STATION.

The work of the Glenwood substation has been planned, during the past fiscal year, to conform to the necessary policy of economy enforced by a 50 per cent cut in the Territorial appropriations for this station. The activities have, therefore, been confined to lines of work requiring little financial outlay or capable of being conducted on a self-supporting basis. The labor force has been reduced to a single workman, most of whose time has been occupied in the performance of daily routine work involved in the care of the live stock. All operating expenses have been reduced to a minimum and the work has been planned with a view to using the returns for continuing the investigations. With funds available for only one laborer and with the numerous daily records required in connection with the trap-nest tests in the poultry pens, the necessity of keeping the climatological records up to date, as well as the numerous duties incumbent upon the superintendent of an experiment station, it has been out of the question for the superintendent to be away from the station on demonstration and extension work for more than a few hours at a time. It is hoped that arrangements may be made during the ensuing year for members of the staff of the central station to substitute for the superintendent at Glenwood and thus enable him to keep in closer touch with the farmers in the outlying portions of the island.

FORAGE CROPS.

One of the most seriously felt wants of the Glenwood dairy farmer is that of a good, nutritious, milk-producing forage crop that can be successfully grown on the farm, one that will not only satisfy the appetite, as do honohono (*Commelina nudiflora*) and Para grass (*Panicum barbinode*), used extensively under the present system of feeding, but also tend to increase the milk flow and replace a portion of the expensive concentrated ration now being used. Both honohono and Para grass make indifferent growth during the colder season of the year, and a habit of strong winter growth would specially enhance the value of such a feed. Australian water, or Paspalum, grass (*Paspalum dilatatum*) has given greatest promise among the grasses under test at the substation, and it is being planted to a limited extent on some of the local dairy farms. The persistent habits of growth of this species and its natural tenacity of life might, however, render its eradication difficult under existing conditions of continued rainfall. The relation of this grass to forage poisoning of stock in the Southern States as reported upon by Brown and Ranck[1] also suggest a possible source of danger from its general exploitation in Hawaii. The authors of the above-mentioned bulletin advance what appears to be conclusive evidence in support of the theory that certain cases of stock poisoning were due to pasturing on Paspalum grass and find the direct cause in an ergotlike fungus which attacks this grass, existing as a parasite on its pistillate flowers. In view of the serious nature of this malady, it would seem that the live stock interests of Hawaii should be safeguarded by effective and rigorous precautionary measures regulating the importation of Paspalum seed. The possibility that other widely distributed local species of this genus, such as the common Hilo grass (*P. conjugatum*), might also serve as a host plant for this fungus would further emphasize the importance of preventing its introduction.

A few volunteer plants of California bur clover were found to be growing on the substation grounds in December, 1915, and their development during the comparatively cold months from December to April was observed with interest. These plants took possession of a garden plat after it had been thoroughly spaded on December 6, 1915, and made rank and rapid growth until removed on April 11, when the plat was cleared for planting to other crops. The supposition that the seed from which these plants grew was introduced through the medium of imported hay and probably lay in the ground for several months before germinating, combined with the fact that a very heavy crop of seed was nearing maturity when the

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[1] Mississippi Sta. Tech. Bul. 6 (1915).

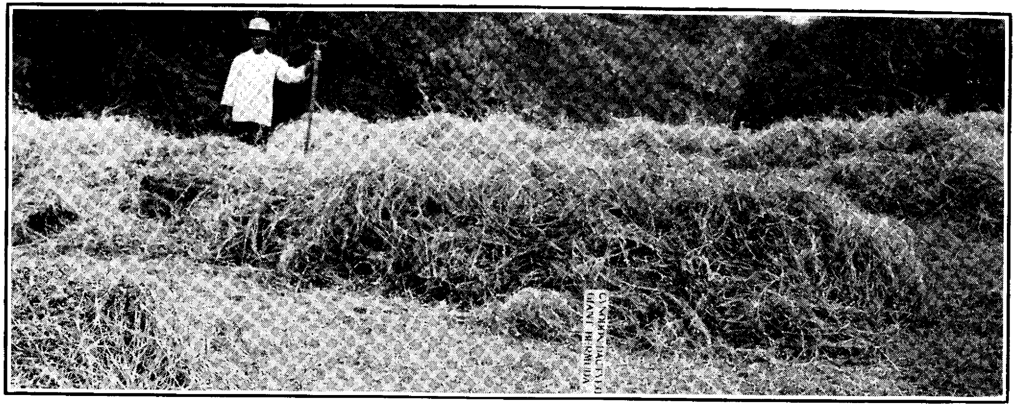

FIG. 1.—GIANT BERMUDA GRASS HAY.

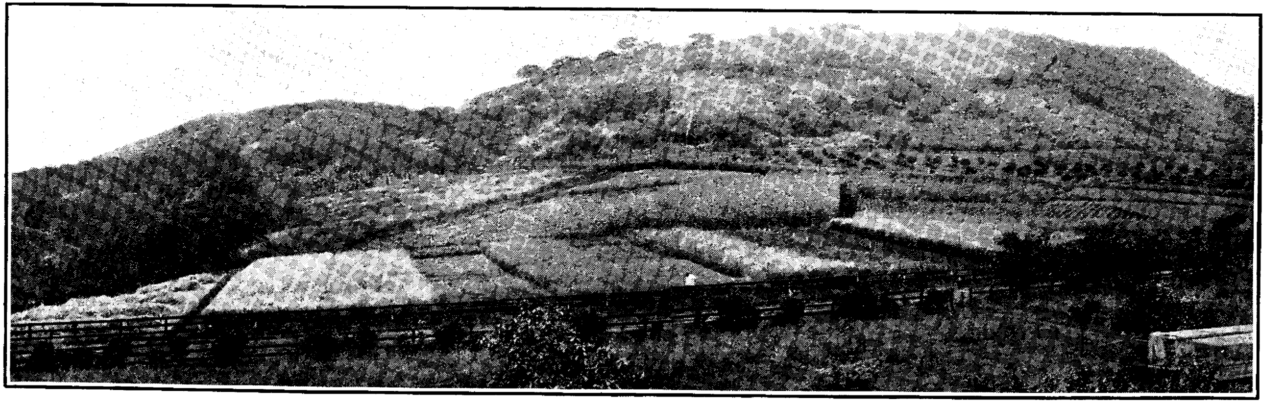

FIG. 2.—VIEW OF EXPERIMENTAL AND DEMONSTRATION PLATS.

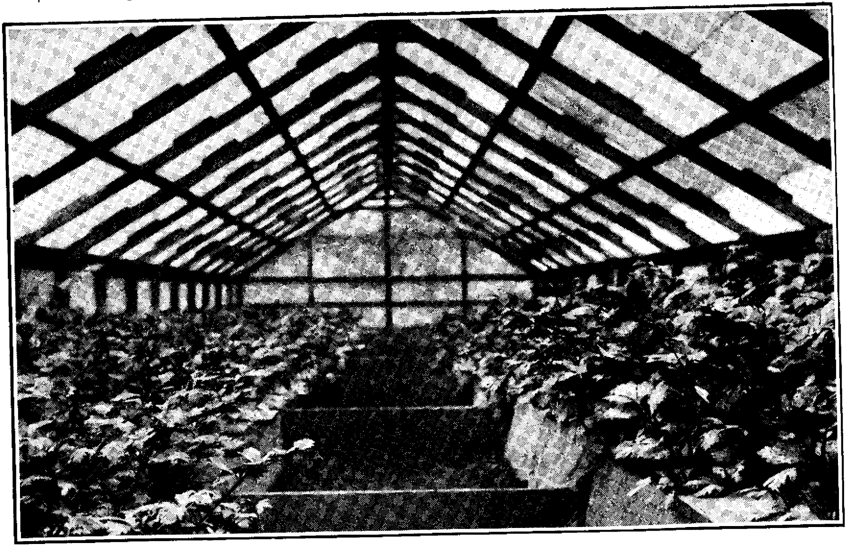

FIG. 1.—CELERY SHELTER HOUSE, GLENWOOD SUBSTATION.

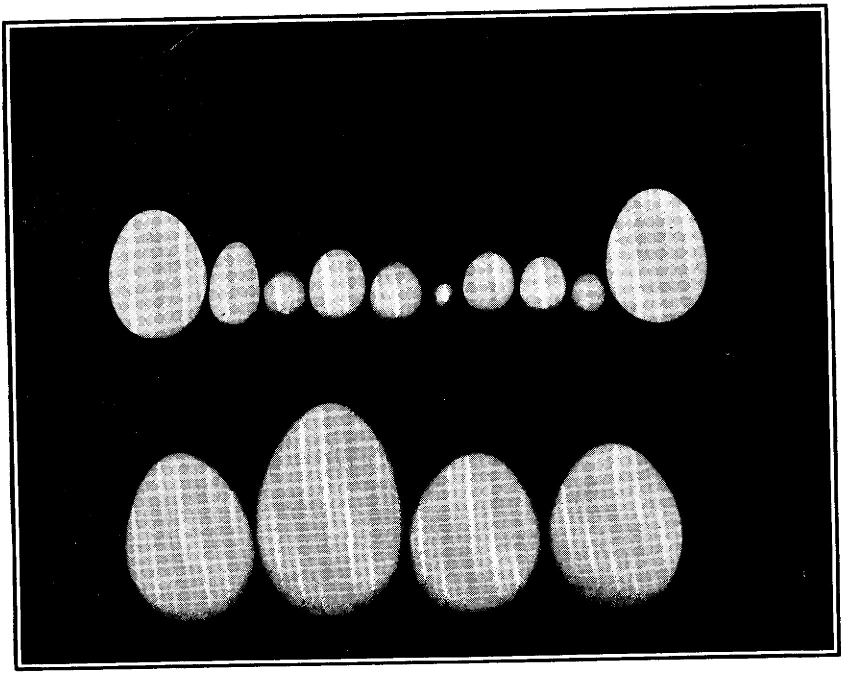

FIG. 2.—CONSECUTIVE EGGS LAID BY PULLETS.

Upper ten eggs laid by pullet No. 112, eight smaller eggs weighing $2\frac{1}{4}$ ounces. Lower four eggs laid by pullet No. 172.

plants were destroyed, leads to the hope that California bur clover will reseed itself under climatic conditions that obtain in this district. A supply of this seed has been ordered and trial plantings will be made during the coming winter season.

NEED OF A SUITABLE HOG FEED.

In the Glenwood district, where practically the entire homestead population is largely dependent upon the sale of dairy products for a livelihood, a keen interest is shown in the problems of hog production, this industry being a natural adjunct of the dairy, where an excess of skim milk is available in varying quantities throughout the year. A strong deterrent, however, to this alluring feature is the high price of supplementary feed and the lack of any suitable grain crop that is known to be profitable for local production. The substation, in its work for the past few years, has given attention to the problem of supplying a satisfactory feed that will constitute a dependable crop under local farm conditions.

On December 10, 1914, a planting of the edible canna (*Canna edulis*) was made on a measured area of 575 square feet. This was harvested on January 14, 1916, yielding a total of 833 pounds, or at the rate of 31.5 tons per acre. The crop was grown on a plat of good garden soil and the yield was probably considerably greater than would have resulted from plantings made under average field conditions. Another trial was begun on the same plat on January 25, 1916, and on April 5, 1916, a field planting was completed on soil of rather low fertility and without the use of fertilizer. A portion of the product dug on January 14 and kept stored at the substation in ordinary bags for a period of three months showed practically no loss from decay, thus indicating the ease and simplicity with which it can probably be handled in a damp, rainy climate where much loss might be expected. Samples of the fleshy rhizomes of the canna, submitted to the station chemist, showed a composition closely comparable to that of the Irish potato.

In this quest for a local product for hog feed a trial planting of Jerusalem artichokes (*Helianthus tuberosus*) was made during the preceding fiscal year on an area of 960 square feet. This crop was dug on November 5, 1915, yielding a total weight of 490 pounds, or, figured in terms of acre yield, a fraction more than 11 tons. A large portion of this planting failed to grow and the stand was estimated at 33⅓ per cent at the time of harvest. Unlike the edible canna, the Jersusalem artichoke has not kept well in storage, being attacked by a moldlike fungus and completely ruined when stored in bags. In working over the garden plat upon which this crop was grown, a number of roots were found on January 25 in a perfect state of preservation. These were planted immediately and showed no growth until the first week in May, when a portion of them was found to be sprouting. These observations would suggest the necessity of digging the crop as needed for feed or of allowing the hogs to dig them at will. For general purposes, delayed harvest or a system of stratification would seem to be necessary.

CELERY-DISEASE CONTROL.

By referring to the tabulated meteorological data at the end of this report (p. 43), it will be recognized that marketable money-making crops that will succeed under conditions at Glenwood and its surrounding territory are decidedly limited. The very high precipitation is an unfavorable element, but the low night temperatures constitute an even more decisive factor in the limitations of general crop production. There are few cash-returning crops that thrive under these peculiar climatic conditions. Celery is a notable exception to this rule. There is a constant demand for celery of good quality, and this is being very inadequately met, most of the limited supply being of foreign origin. The one serious problem involved in the production of celery here seems to be the prevalence of late blight, caused by the fungus *Septoria petroselini apii*, and as long as this disease can be controlled, celery grows with unsurpassed luxuriance. The heavy rainfall and the frequency of rainy days preclude efforts to control this disease on unprotected plantings by the usual methods of spraying. During the past year the substation has inaugurated a line of experimental tests in which an effort is being made to produce the crop under shelter, a frame building (see Pl. VI, fig. 1) 72 by 16 feet and covered with cheesecloth having been constructed for these trials. This work has included the disinfection of seed with a weak formalin solution before sowing and the spraying of plants in the usual manner with Bordeaux mixture prepared in accordance with the 5:5:50 formula. At the time of this writing the progress of these trials is encouraging, but maximum efficiency would require complete overhead protection in the construction of which a sufficient amount of glass should be employed to insure an optimum of sunlight.

POULTRY WORK.

The poultry-breeding work being conducted at the substation with the object of increasing both the average number and the average size of eggs through selective breeding has been of unusual interest (Pl. VI, fig. 2). Complete trap-nest and individual egg-weight records have been kept throughout the year. The past season's hatch consists of 212 birds, including both sexes, ranging from two to less than five months old at the time of this writing. The pullets from the first hatch are just beginning to lay. The greater number of these birds are single-comb White Leghorns from pullet matings. The mothers of these birds were selected from trap-nest and egg-weight records covering a period of approximately four months between the time their first eggs were laid and the beginning of the hatching season. Like records of the entire flock of about 160 birds hatched during the season of 1915 have been kept throughout the year, and the selection of breeders for the past season's hatch, with one or two eliminations and a few additions, will hold for another breeding year. In other words, the selections made from records of the first four months of laying have, in this case, proved generally satisfactory. With the exception of 28 birds, the entire flock of the past year's rearing has been carefully pedigreed and the complete poultry record to date amounts to about 35,000 separate entries.

METEOROLOGICAL RECORDS.

During the past fiscal year the substation has assumed the duties of a cooperative observer for the Hawaiian section of the Climatological Service, United States Weather Bureau, daily records of temperature and rainfall having been taken in this capacity since January 1, 1916. As these climatic factors have an important bearing on general crop production, these data are summarized and presented in the following table:

Summary of meteorological records at Glenwood substation from Jan. 1 to June 30, 1916.

Month.	Absolute temperature.		Mean temperature.		Total precipitation.	Number of rainy days.	Number of clear days.
	Maximum.	Minimum.	Maximum.	Minimum.			
	°*F.*	°*F.*	°*F.*	°*F.*	*Inches.*		
January	79	47	72.60	54.40	19.99	27	2
February	79	46	74.79	53.55	4.73	17	2
March	80	49	72.51	56.64	17.38	24	3
April	77	53	72.42	57.62	18.50	27	2
May	77	53	72.87	58.00	43.47	29	0
June	74	53	71.37	58.87	17.45	30	0
Six months	....	....	72.76	56.51	121.52	154	9

REPORT OF THE TERRITORIAL MARKETING DIVISION.

By A. T. Longley.

During the past year there have been many changes for the better at the division in both organization and equipment, which to a large extent accounts for the heavy increase in the number of consignments handled as well as in the volume of the sales. The division, after three years of effort, is now in a position to give the producers of the Territory much better service than ever before.

The increased appropriation made by the last Territorial legislature and the new building provided for at the same time have been of the greatest assistance to the division in working up the business of the small producer. The facilities for handling all kinds of farm products are now first class, except that a cold-storage plant for the increasing consignments of dressed meats is yet to be installed. The new quarters are located on Mauna Kea Street, just off Queen Street, and contain offices, salesrooms, rooms for candling eggs, fumigating, dressing poultry, and a garage. There were insufficient funds left after the building was completed to provide for a cold-storage plant as originally planned. As a result a great deal of time is now lost and considerable expense to the producer incurred in putting the dressed meats in local private cold-storage plants.

On July 1, 1915, a branch of the division was opened in San Francisco to facilitate the sale of Hawaiian agricultural products on the mainland, particularly pineapples. During the summer of 1915 pineapple canneries were unable, on account of unsettled market conditions, to take all the fruit offered by the small producers, and, as a great deal of it could not be sold locally, the division endeavored to find a market for the fresh fruit on the mainland. In connection with the establishment of the San Francisco branch and the marketing of pineapples the superintendent made a trip to San Francisco and as far east as Chicago. It was found that the report of high prices paid for pineapples in Chicago was erroneous, and that even though fair prices ruled, the Cuban and Isle of Pines fruit could be placed on the Chicago market in better condition and at $1 a crate less than Hawaiian fruit.

The amount of pineapples offered to the division for shipment to the coast during last season was in excess of the number which could be profitably disposed of there and the mistake of accepting too many was made. The shipments during July, 1915, netted about $8 a ton for the fruit in the field, but when the shipments were increased the returns soon became very unsatisfactory, owing in part to the heavy spoilage en route and in part to the glutting of the market by the heavy shipments of the division and also of private parties in the islands. An attempt was made to relieve the congested condition of the market by sending trial carloads to cities as far east as Denver and Kansas City. The heavy spoilage on these shipments, even though the pines were repacked at San Francisco and the spoiled and spotted fruits removed, was such as to result in severe losses on all these shipments. The spoilage was heaviest when the pines were overcrowded on the steamer without adequate provision for ventilation and cooling. During the year a total of 23,532 crates were shipped for which returns have been received. The returns on these were not quite sufficient to cover freight charges, cost of crates, and other marketing expenses.

The quality of produce received by the division is steadily getting better, and shippers are paying more attention to grading and packing. Some producers who are putting up a uniform article are getting higher prices for their products, due to the increased demand for first-class island produce. The marketing of eggs had caused a great deal of trouble heretofore, but since the division established three grades—"selects," "firsts," and "seconds"—the marketing of eggs has been much simpler. "Select" eggs must have the name and address of the producer and his guaranty stamped on each egg. There have been more calls for stamped eggs at 3 cents above the market price than the division has been able to supply.

Practically all the island agricultural products have been represented in the individual consignments received by the division, ranging in size from 1 dozen eggs to 30 carcasses of beef. The consignors were of many nationalities.

Up to January, 1916, no expert accountant had ever gone over the bookkeeping system of the division since it was first put under the supervision of the experiment station in 1913, and as the business was outgrowing the old system, an expert accountant was called in to revise the system and balance the books. The new system has been in operation for six months and is proving satisfactory. In accordance with the new plan, the books are audited each quarter by an expert accountant. Beginning with July 1, 1916, a cost-accounting system is planned for all departments of the business.

To facilitate the handling of small sales to consumers a retail vegetable and fruit department and a retail butcher shop were opened on June 1, 1916. The sales from these departments are practically all for cash, and purchasers are required to take their purchases with them. By this arrangement the cost of bookkeeping and delivery is saved the purchaser.

The establishment of these two new departments reduces the consignment bookkeeping a great deal, for the reason that large quantities of produce are charged to these departments by the consignment department, thus doing away with the many small credits that had to be made when retail sales were made direct from consignments. The returns from the retail branch for the month of June have been very satisfactory, and it is expected that these departments will become self-supporting.

In order to get better prices for the producers on the island of Hawaii, especially in the vicinity of Hilo, the Hawaiian board of supervisors is considering a proposition to subsidize a branch of the Territorial marketing division in Hilo. Such a branch would be of great assistance in regulating the supply in Hilo and in shipping any surplus produce to Honolulu.

The sales of the division during the past year have increased considerably over previous years, and the cost of marketing produce has been reduced. The sales for the different branches of the business for the year are as follows:

Local consignments (produce received on consignment and sold locally)	$66,977.94
Sales of purchased merchandise (feed, seed, crates, packing material, and produce purchased on the outside to fill orders)	43,087.29
Mainland consignments (all shipments sent to the San Francisco branch to be sold for the account of the division)	17,659.22
Gross total	127,724.45
Less sales from consignment branch to retail branch	6,638.67
Net total	121,085.78

During the coming year the division plans to get in closer touch with producers and their marketing difficulties by having representatives visit their farms and look into local markets. It is planned to keep a more accurate record of what is being produced and when it will be ready for market.

Up to the end of this fiscal year the superintendent, in addition to supervising the work of the division, also attended to many duties as clerk of the experiment station. Being relieved of the latter duties beginning July 1, 1916, he will devote his entire time to the work of the marketing division.

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Issued March 5, 1918.

HAWAII AGRICULTURAL EXPERIMENT STATION,

J. M. WESTGATE, Agronomist in Charge.

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION.

1917.

UNDER THE SUPERVISION OF

STATES RELATIONS SERVICE,
Office of Experiment Stations,
U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON
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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the States Relations Service, United States Department of Agriculture.]

E. W. ALLEN, *Chief of Office of Experiment Stations.*

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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J. B. THOMPSON,[1] *Assistant Agronomist, in Charge of Glenwood Substation.*
ALICE R. THOMPSON,[1] *Assistant Chemist.*
C. A. SAHR, *Assistant Agronomist.*
A. T. LONGLEY,[1] *In Charge of Cooperative Marketing Investigations.*
J. W. LOVE, *Executive Clerk.*

LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, July 17, 1917.

SIR: I have the honor to transmit herewith and to recommend for publication a report of the Hawaii Agricultural Experiment Station, 1917.

Respectfully,

J. M. WESTGATE,
Agronomist in Charge.

DR. A. C. TRUE,
Director States Relations Service,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
D. F. HOUSTON,
Secretary of Agriculture.

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[1] On leave.

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REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1917.

SUMMARY OF INVESTIGATIONS.

By J. M. WESTGATE, *Agronomist in Charge.*

INTRODUCTION.

The present world food shortage has emphasized more clearly than ever before the isolated position of the Hawaiian Islands and their dependence on outside sources for their food supply. The focusing of attention on the vital necessity for the local production of a much greater proportion of the food consumed on the islands has led to a gratifying response on the part of numerous organizations and individuals. It is fully realized that in making serious efforts to become self-supporting, Hawaii is doing a real service both to herself and to the country at large, as every pound of food produced here releases just that much for use elsewhere, besides providing the best form of insurance against the possible consequences of complete isolation from the mainland.

As far as practicable the resources and activities of the station have been brought to bear directly on the local production of foods and forage crops. In all this work, there has been the most cordial cooperation on the part of the various individuals, organizations, and institutions concerned. In competing with the agricultural districts of the mainland, certain vital difficulties are encountered on the islands, and means of overcoming these are being sought. The hilly, often rocky, land available for the production of food crops usually requiring much hand labor in its cultivation, the isolated nature of most of the agricultural districts, and the difficulties encountered in reaching markets (some sections having only a monthly boat upon which shipments can be made), all combine to render the cost of production greatly in excess of that of mainland sections. Not the least of the drawbacks to agriculture in Hawaii is the multitude of insect enemies and plant diseases, the control of which, unchecked by freezing temperatures, demands continual vigilance on the part of the would-be producers who often fail to realize the necessity even for such precautionary or remedial measures as spraying. The building up of a strong demand for locally grown products would do much to overcome the present situation, but it appears necessary to subsidize certain lines of agriculture before it will be possible to produce sufficient food to enable the people of the islands to exist if suddenly cut off from the mainland.

BUILDINGS AND GROUNDS.

During the year a set of farm buildings, including a combination stable and barn and a 4-room residence for the substation foreman, was erected at the Castner substation. The type of construction of the barn is such that the attic is available for curing forage crop samples while the space beneath the first floor is utilized for the storage of implements. Inasmuch as there is no convenient supply of household water, redwood tanks have been installed to catch the rain water from the buildings.

COOPERATION WITH MILITARY POSTS.

The national food emergency situation has led to the establishment of tracts for growing vegetables on a number of military reservations on the island of Oahu. In carrying out this work, the experiment station has been able to render material assistance in the selection of suitable soils, has made recommendations regarding crops to be grown, and in some instances has been able to supply plants and seed produced on the station grounds. On the Schofield Barracks reservation, over 100 acres of sod and guava land has been cleared and broken up and the larger part is already planted to cassava and sweet potatoes.

The forage crop work on Schofield Barracks reservation at Castner was definitely inaugurated July, 1916, and during the year a considerable number of forage and food-crop production experiments have been started. The principal difficulties encountered are lack of sufficient rainfall, the presence of strong winds, and the high manganese content of the soil. About 50 varieties of grasses, forage plants, and food crops are under test.

HORTICULTURAL INVESTIGATIONS.

The growth and development of seedling pineapples has constituted an important line of work during the past year. Several thousand seedlings have been set out in individual pots, and as fast as these attain sufficient size they are transferred to cooperating plantations where they will be brought to fruit under regular field conditions. Through the cooperation of the Office of Foreign Seed and Plant Introduction, Bureau of Plant Industry of the United States Department of Agriculture, two varieties new to the islands have been introduced, one the MacGregor from Queensland, Australia, which is said to be immune to the black heart disease; the other the Commonwealth, also from Queensland, which was developed from a seedling.

Recognition of the potential value of small home vineyards has led to the establishment of a cooperative vineyard of about an acre in extent where various fertilizer, variety, and cultural experiments are in progress. The principal work with avocados has been in connection with the development of a winter-ripening type with a rind sufficiently hard and tough for protection from the fruit fly and for profitable shipment. Seven different varieties of avocado have been introduced from California. A number of mango hybrids have been produced in an attempt to combine the several good qualities of the different varieties. One of the handicaps to tomato growing in the islands is attack by the melon fly. The small native tomato is immune to these attacks and hybrids relatively immune have been developed by crossing the native tomato with the Earliana variety. Thousands of seedlings from these hybrid plants are being grown throughout the islands and watched by several hundred individuals in connection with their cooperative home gardens. The most desirable individual plants will be used in the development of a relatively immune standard-size tomato.

CHEMICAL INVESTIGATIONS.

As its most important line of work, the chemical division has been following up the preliminary results obtained from the spraying with iron sulphate of pineapple plants growing on manganese soil. Iron sulphate has been ordered in carload lots by a number of the local pineapple companies, the practice of spraying having been adopted wherever manganese soils occur in the pineapple plantings. Because of the presence of large quantities of manganese in the soil, a large acreage of otherwise good pineapple land has been allowed to stand idle in the past, but with the problem of counteracting the effects of manganese on pineapples solved, these areas are now being broken up and planted. Over 5,000 acres of manganese land was successfully treated with iron sulphate spray during the past year. Pineapple wilt is also giving considerable concern to local growers and a number of experiments on means of controlling the trouble are under way, the most promising of these appearing to be the application of suitable quantities of lime to the wlit-affected soils.

Fertilizer experiments with rice, banana, and pineapple have been inaugurated in cooperation with various growers throughout the islands. The present food shortage has made especially important the drying of such food products as would otherwise be lost from decay if not used with reasonable promptness. Preliminary experiments have shown that locally grown cassava, sweet potatoes, taro, etc., can be readily dried by exposure to the sun and wind on suitably constructed driers, and that the resulting dried product can be stored without apparent deterioration.

EXTENSION WORK.

The work of the extension division has been prosecuted along a number of lines employing several methods of approach. Timely articles in local newspapers have brought vital facts before the reading public. As the character of the regular station bulletins and press bulletins is such that they do not lend themselves readily to the promulgation of miscellaneous data on short notice, the station has begun to issue a series of extension bulletins, an important innovation, as in this way a channel is provided through which items of a general agricultural nature can be brought immediately to the attention of those interested. The manner in which these extension bulletins have been welcomed has furnished evidence of their usefulness. In addition to the above, numerous field trips have been taken by various members of the staff for the purpose of explaining and demonstrating improved agricultural operations such as spraying, budding, grafting, pruning, and garden management. Five demonstration farms, maintained cooperatively with the owners of the farms, have furnished numerous object lessons that appeal alike to the members of all races irrespective of color or language. The food-crop production campaign has called for much extra work on the part of those directly interested in the extension phases of the activities of the station. The manifest appreciation of this work has been gratifying. A decided stimulus to numerous lines of agricultural endeavor was given by the two agricultural county fairs in the success of which the work of the extension division was an important contributing factor.

PLANT-DISEASE INVESTIGATIONS.

The division of plant pathology was installed at the station June 1, 1916, but most of its development has taken place during the past fiscal year. The division now occupies three rooms, namely, a combined office and library, a laboratory for microscopical and general work, and a separate gas-equipped laboratory room where culture media are prepared. The diseases of the potato, banana, and celery have received the greatest amount of attention during the season. The potential importance of the Irish potato crop, combined with the presence of several serious diseases, has made the potato-disease project the most important line of work of the division. The emergency food-production campaign has led to repeated calls on the station pathologist for advice and assistance regarding the best means of overcoming the various plant diseases and insect pests of the garden. To supply this information, multigraphed sheets of directions have been prepared.

GLENWOOD SUBSTATION.

The work of the Glenwood substation has been along poultry, dairy, and forage and food-production lines. Attention has been focused on the poultry work as it has proved the most profitable of any line of work so far inaugurated at the substation. Trap-nest and egg-weight records for the flock have been maintained throughout the year, affording the best possible basis for the selection of eggs for distribution for hatching purposes. The work with the edible canna has been continued and tubers from the original planting have been distributed throughout the islands in connection with the emergency food crop-production work. A number of different plantings of celery have indicated that with careful attention to spraying at the proper time the crop is reasonably certain when grown either under cloth or in the open.

Among the forage plants experimented with, the common bamboo grass has made a creditable showing under the adverse climatic conditions obtaining throughout most of the year. The ravages of cutworms make it difficult to establish a stand of alfalfa, but this difficulty can be overcome by transplanting well-grown seedlings to the rows in the field, as in transplanting tomato plants. Vigorous, isolated plants of alfalfa several years of age attest the possibilities of the crop when once established. A number of varieties of bur clover were tried with fair results. Not sufficiently erect in their habit of growth to allow easy cutting for green forage, the bur clovers are of most promise for use in pastures.

During the autumn of 1916 the substation maintained an active interest in the local county fair. This fair brought to light the "Hamakua hybrid," a very promising, relatively blight-resistant potato which is apparently a cross between a local Portuguese Red potato and some mainland variety, several of which were being grown in association with the Portuguese Red potato at the time of this discovery. Comparative tests for disease resistance were at once started at the substation, and the showing made by the new variety as compared with the mainland varieties was remarkable, the blight completely destroying the vines of the ordinary varieties a considerable time before the crop had fully matured, while the resistant variety was attacked only at a considerably later date and then not seriously. As comparative tests on the other islands have not shown such striking results as at the substation, for the time being most of the extension work with this new variety will be carried out on the island of Hawaii, where it appears to be of the most promise.

AGRONOMIC INVESTIGATIONS.

The work of the agronomy division has been devoted to a continuation of experiments with rice, taro, potatoes, various leguminous crops, and forage grasses.

As its most important work, the agronomy division has established a substation at Castner, Oahu, on the Schofield Barracks reservation in cooperation with the military authorities. Plats have been laid out and tests of varieties, kinds and amount of fertilizers, and cultural methods have been inaugurated. These experiments were sufficiently under way to furnish much valuable information for use in connection with the emergency food and forage production work inaugurated in the spring of 1917.

TERRITORIAL MARKETING DIVISION.

The total volume of business transacted by the division during the year amounted to $139,519.05, as compared with $121,085.78 for the preceding year. Consignments numbering 2,538 and consisting of 60 different kinds of island products, were received and sold. The number of different producers consigning to the division was 474.

The retail vegetable and meat branches, while not quite paying expenses, proved a most valuable adjunct to the wholesale consignment department in that they furnished an outlet at all times for the produce consigned by the small farmer. Before the establishment of the retail branches, it frequently happened that produce could not be sold to the local retail stores except at a great sacrifice. This was apparently because the island supply was not regular and dependable and retail dealers made standing orders for regular shipments each week from the mainland. These regular shipments were ordinarily sufficient to meet the needs of the retail customers and great difficulty was experienced in moving the locally grown produce.

In the autumn of 1916, agricultural county fairs were held at Hilo, Hawaii, and at Wailuku, Maui. Demonstrations were given at each of the best methods of grading and shipping island-grown produce of various kinds.

The recent session of the legislature appropriated $30,000 for the operating expenses of the division for the enusing biennium and also provided $5,000 for extension work among the farmers, looking to the standardization of products, improved methods of crating, etc. A revolving fund of $15,000 was provided to permit more prompt payment of consignors. An additional revolving fund of $2,500 for the purchase of seed was also made available. On July 1, 1917, the Territorial marketing division was transferred to the Territorial Board of Agriculture and Forestry.

PUBLICATIONS.

The following publications have been issued during the year:

Annual Report for 1916.
Bulletin 41, Phosphate Fertilizers for Hawaiian Soils, and Their Availability.
Bulletin 42, Composition of Hawaiian Soil Particles.
Bulletin 43, Chemical Studies of the Efficiency of Legumes as Green Manures in Hawaii.
Press Bulletin 51, The Spraying of Yellow Pineapple Plants on Manganese Soils with Iron Sulphate Solutions.
Press Bulletin 52, Comparative Value of Legumes as Green Manures.
Extension Bulletin 1, Extension Notes I.
Extension Bulletin 2, Extension Notes II.

REPORT OF THE HORTICULTURAL DIVISION.

By J. Edgar Higgins.

The principal work of the horticultural division during the year was with the pineapple, avocado, mango, grape, and tomato, although the national food shortage emergency has called for considerable attention to variety and cultural tests with vegetables. James H. Cowan, who has been associated with the horticultural division since September, 1913, took up the projects left by Valentine S. Holt when he resigned from the station August 31, 1916.

PINEAPPLE INVESTIGATIONS.

The seedling pineapples of station Nos. 3059 and 3060 have been fruiting since June, 1916. The seeds from which these grew were planted in October, 1912. It thus required three years and eight months from seeding for the first of these to mature fruit. While there have been very marked variations among these, as recorded in the annual report for 1916, none has thus far shown a combination of characters of sufficient desirability to justify the establishment of a new commercial variety. This, however, is not surprising or disappointing, as it would be quite remarkable for any new forms of unusual value to appear among so few chance seedlings as were included in these first two lots planted.

Seeds have been found in the fruits of these seedlings with undesirable frequency, giving rise to suspicion that seed bearing may be an inherited character in them. Such a conclusion, however, is not justified by the evidence in hand, for, although a large percentage of the fruits had some seeds, it is to be remembered that each seedling is more or less a distinct variety and may be subject to the effects of pollen from some of the neighboring plants, of the same or of different origin, while it may be wholly sterile to its own pollen. If this be the case, as is true in general of the Cayenne variety, the supposed progenitor of all of the seedlings grown from seeds collected at the pineapple canneries, then it would be possible to propagate any such seedlings by slips, crowns, or other asexual parts and, by segregating them from other varieties, to avoid seed production. As no variety of pineapple habitually producing seeds can be considered either for canning or for the fresh fruit market, it will therefore be necessary to examine the promising seedlings carefully in order to determine whether seed production is due to inherited character or to environment.

There are now under cultivation about 2,240 plants from seeds supplied by a number of pineapple canneries and planted during the winter of 1915–16. Of these, about 350 which had attained sufficient size were planted out in the pineapple fields, where they are under the same conditions as commercial plantings. During the past fiscal year all available pineapple seeds from the canneries have been planted, but seeds appear to have been of less frequent occurrence than during the winter of 1915–16.

A hundred or more hybrids or crossbreds now under cultivation were grown from seeds of a Cayenne plant, several of whose flowers had been fertilized with pollen from the Queen variety. No precautions were taken to prevent self-fertilization, as the rarity of this occurrence seems to indicate that such precautions are hardly necessary. Further crossing of pineapples had been planned, but had to be deferred on account of the pressure of work in connection with the food campaign during the most favorable hybridizing season.

Selections have been made in the fields of several hundred plants to be propagated by slips or by suckers to determine the constancy of certain characters under asexual propagation.

Two new varieties have been introduced through the cooperation of the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry. One of these is the MacGregor, a variety from Queensland, Australia, which is claimed to be immune to the black heart, a disease which resembles in many ways and may be identical with the brown rot of pineapples described by Larsen[1] and occurring in Hawaii. The following notes concerning this variety are taken from the Queensland Agricultural Journal for February, 1916:

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[1] Larsen, L. D. Diseases of the pineapple. Hawaiian Sugar Planters' Sta., Path. and Physiol. Bul. 10 (1910), pp. 28–36

> We have received from Mr. E. Smallman, Campsie Fruit Farm, Ormiston, the accompanying photograph of that portion of his orchard which is devoted to the cultivation of a special variety of pineapple which he obtained 10 or 11 years ago from what was known as Skyring's Farm, Bulimba. The plants are most prolific bearers, as will be seen by the illustration, which shows them in full bearing just before Christmas. These were only planted in September, 1914, and a single quarter acre yielded 2,500 pines, averaging about 4½ pounds each in weight. One of the specially good qualities of the fruit is that it keeps well and never develops "black heart." A case of the fruit was sent to Sir William MacGregor, late governor of Queensland, 12 months ago, and he expresses his unqualified opinion of the pines as the finest in flavor and texture that had come under his notice when in Queensland. Mr. Smallman brought two very fine specimens to this office, each of which went over 4½ pounds and not picked samples. They were quite ripe but very firm in the flesh, and their flavor quite deserved all that Sir William MacGregor said of them. There having been only one plant originally obtained it took several years' planting of "nibs" and tops before the present area was fully planted and bearing.

Plants of the MacGregor variety were supplied by J. F. Bailey, of the botanic gardens of Brisbane, Australia.

The other variety introduced is the Commonwealth, secured through R. W. Peters, director of the Queensland Acclimatization Society. This is one of the society's seedlings and is understood to be of much promise in Australia. Both of these lots of plants arrived by mail in good condition, having been packed dry.

GRAPE EXPERIMENTS.

In connection with investigations of fruits suited to tropical conditions, some experiments were undertaken in the growing of grapes. The grape has long been under cultivation in Hawaii, chiefly by the Portuguese settlers, to whom is probably due the credit of having introduced the variety which has been most successful in these islands, supposedly a strain of the Isabella, which is reported to have been introduced on an immigrant ship arriving here from Madeira. Though grapes of other varieties have been introduced from time to time, none has established itself in the islands except the one just referred to, an indication merely that this variety is very hardy and resistant to disease, as probably there are many other varieties which can be made to prosper. Small vineyards are to be found in many parts of the Territory, particularly in the vicinity of Honolulu and Hilo, in the district of Kona, Hawaii, and in Makawao and the lower slopes of Haleakala on the island of Maui. Near Honolulu and the other important towns a considerable portion of the crop is consumed as fresh fruit, selling at 10 to 12 cents per pound retail. A small wine industry has grown up at several points, but the Isabella variety is not particularly adapted to wine purposes, as it is apparently necessary to fortify it heavily to prevent deterioration.

With the rapidly increasing population of the island of Oahu and the growing demands of steamships calling at the islands, there appears to be an opportunity to increase the trade in fresh grapes. As little experimental work has been done on the grape in Hawaii, it seemed desirable to embrace an offered opportunity to undertake a cooperative experiment on a small scale which would make it possible to attack some of the problems relating to this minor industry, Willard Brown, of Wahiawa, Oahu, supplying the land, labor, and fertilizers, the experiment station furnishing the plants and giving advice on their care and cultivation. A little vineyard of about one acre in extent, located at Wahiawa about 26 miles from Honolulu, at an elevation of approximately 1,100 feet, on a clay loam soil with a rather retentive subsoil, was set in March, 1916, with plants at distances of 8 by 10 feet. Only the Isabella variety was used, it being intended to graft upon these plants any other varieties which later might be introduced into the experiment, for, as mentioned above, this variety has proved well adapted to local conditions and the limited experience of the past indicates that the few other varieties tried have done better on Isabella roots than on their own.

Fertilizer experiments.—One of the first problems which it seemed desirable to investigate was that of fertilizers. For this purpose the vineyard was laid off in three divisions, as indicated in figure 1. In divisions 1 and 2 certain combinations of two of the fertilizing elements were applied, while division 3 was treated with a complete fertilizer, with the exception of rows Nos. 13, 14, and 15, which were left unfertilized, row No. 14 being held as a check. All fertilizers were applied on March 14, 1916.

In division 1 there were 10 plants in each row, and in division 2, 9 plants. The first and last plants in each of the fertilized rows in division 1 were left without fertilizer and also the first plant in each fertilized row in division 2, thus leaving two unfertilized plants to separate the fertilized rows of division 1 from those of division 2. This is indicated on the chart (fig. 1) by a break in the line.

In division 1 the 8 plants from No. 2 to No. 9, inclusive, in row No. 2 received 2 pounds of nitrate of soda, or the equivalent of one-fourth pound per plant. This was at the rate of only 136 pounds of nitrate of soda per acre distributed evenly over the entire area. Since the plants set out were small, with roots only a few inches long, the fertilizer was applied exclusively to the hole, about 3 feet in diameter at the surface, in which the plants were being set. If the whole area had received fertilizer equivalent to that applied to the feeding area, the amount would have been several times that indicated above.

The corresponding 8 plants in row No. 5 of this division received 2 pounds of sulphate of ammonia, or the equivalent of one-fourth pound per plant. In row No. 8 the application was 4 pounds of blood, or the equivalent of one-half pound per plant. The corresponding 8 plants of row No. 11 received 4 pounds of sulphate of potash, or the equivalent of one-half pound per plant. Two rows were left unfertilized between each two fertilized rows. Row No. 13 was therefore 16 feet from any fertilized plants, and, although an outside row, it could fairly be taken as a check, since the land beyond for 20 feet or more was cultivated, as well as that immediately surrounding the plants. Also this row was on the side away from the prevailing winds.

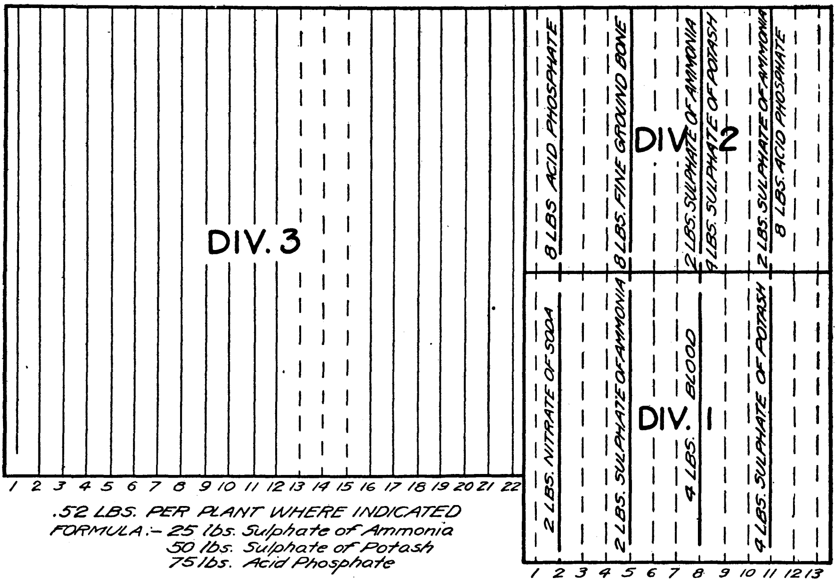
DIV. 3
DIV. 2
DIV. 1
8 LBS. ACID PHOSPHATE
8 LBS. FINE GROUND BONE
2 LBS. SULPHATE OF AMMONIA
4 LBS. SULPHATE OF POTASH
2 LBS. SULPHATE OF AMMONIA
8 LBS. ACID PHOSPHATE
2 LBS. NITRATE OF SODA
2 LBS. SULPHATE OF AMMONIA
4 LBS. BLOOD
4 LBS. SULPHATE OF POTASH
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
1 2 3 4 5 6 7 8 9 10 11 12 13
.52 LBS. PER PLANT WHERE INDICATED
FORMULA:– 25 lbs. Sulphate of Ammonia
50 lbs. Sulphate of Potash
75 lbs. Acid Phosphate

FIG. 1.—Chart of vineyard, showing fertilizer experiments. The heavy lines indicate fertilized rows and the broken lines unfertilized rows.

In division 2 the last 8 plants in rows Nos. 2, 5, 8, and 11 were treated with fertilizer. Row No. 2 received 8 pounds of acid phosphate, or the equivalent of 1 pound per plant; row No. 5, 8 pounds of finely ground steamed bone, or the equivalent of 1 pound per plant; row No. 8, 2 pounds of sulphate of ammonia and 4 pounds of sulphate of potash, or the equivalent of one-fourth pound and one-half pound, respectively, per plant; row No. 11, 2 pounds of sulphate of ammonia and 8 pounds of acid phosphate, or the equivalent of one-fourth pound and 1 pound, respectively, per plant.

In division 3, with 16 plants to the row, a complete fertilizer consisting of 25 pounds sulphate of ammonia, 50 pounds sulphate of potash, and 75 pounds acid phosphate was applied at the rate of 8.32 pounds per row, or the equivalent of 0.52 pound per plant. Rows Nos. 13, 14, and 15 were left unfertilized, only row No. 14 being considered as a check, however, since there was a possibility that the plants in rows Nos. 13 and 15 might use the fertilizers from adjoining rows.

Summary of results of fertilizer tests.—In divisions 1 and 2 measurements were made on December 14 of each plant in the fertilized rows and in the check row. In the case of division 3, all plants in row No. 14 were measured and also the plants of an average fertilized row. In all cases the total length of the plants was measured, including the growth made prior to setting out (the plants were fairly uniform at that time). The accompanying tables indicate the effects of fertilizing:

Comparative growth of fertilized and unfertilized grapevines, Mar. 14 to Dec. 14, 1916.

DIVISION 1.

Row No.	Fertilizer applied per plant.	Plant No. 1.		Plant No. 2.		Plant No. 3.		Plant No. 4.		Plant No. 5.		Plant No. 6.		Plant No. 7.		Plant No. 8.		Total growth.		Average growth.	
		Ft.	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*
2	Nitrate of soda, 1/4 lb.	3	9	6	3	11	7		6	1	3	2	7		8		8	27	3	3	4.8
5	Sulphate of ammonia, 1/4 lb.	4	0		10		0		6		0		9		5		6	7	0		10.5
8	Dried blood, 1/2 lb.	1	9	2	1		0		7	1	2		7		6		0	6	8		10.0
11	Sulphate of potash, 1/2 lb.	1	1		0		11		0		9		8		10		0	4	3		6.3
13	Unfertilized		4		7		10		6		6		0		4	2	2	5	3		7.8
	DIVISION 2.																				
2	Acid phosphate, 1 lb.	12	0	25	6	1	3	8	10	10	10	7	0	4	5	15	0	84	10	10	7.2
5	Fine ground bone, 1 lb.	46	4	53	10	3	0	19	0	23	5	16	5	2	0	17	2	181	2	22	7.7
8	Sulphate of ammonia, 1/4 lb., sulphate of potash, 1/2 lb.		7		0	10	5	15	0	11	4		7		8		9	39	4	4	11.0
11	Sulphate of ammonia, 1/4 lb., acid phosphate, 1 lb.		4	11	0	1	10	8	3		8	6	0	18	8	18	8	65	5	8	2.1
4	Unfertilized	3	0	9	4	22	3	11	0		7	2	4		0	3	11	52	5	6	6.6

Comparative growth of fertilized and unfertilized grapevines on division 3, Mar. 14 to Dec. 14, 1916.

	Plant No. 1.		Plant No. 2.		Plant No. 3.		Plant No. 4.		Plant No. 5.		Plant No. 6.		Plant No. 7.		Plant No. 8.		Plant No. 9.	
	Ft.	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*
Fertilized row	3	6	6	10	3	0	12	11	12	0	5	0	19	7	19	11	17	0
Unfertilized row		10		6		7		11	2	5		3	1	4	6	9	3	8

	Plant No. 10.		Plant No. 11.		Plant No. 12.		Plant No. 13.		Plant No. 14.		Plant No. 15.		Plant No. 16.		Total growth.		Average growth.	
	Ft.	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*
Fertilized row	27	0	17	2	7	7	18	4	13	4	6	3	9	2	198	7	12	4.0
Unfertilized row	3	3		0		11		0	1	3	1	5	1	8	25	9	1	7.3

The increase of growth produced by sulphate of ammonia and by dried blood was almost negligible, and while in the nitrate of soda row there was an increase of nearly 3 feet, it will be observed that this growth was not at all uniform, the results justifying slight confidence in using nitrate of soda alone as a fertilizer. Apparently nitrogen is not the dominant need of grapevines on this soil, or else certain limiting factors render the use of nitrogen alone of very little benefit.

As potash used alone in the form of sulphate failed to produce any beneficial results, it may be concluded that limiting factors other than potash were operative in this case also.

It will be seen that 1 pound of acid phosphate per plant produced a fairly uniform increase in the growth of the plants, which averaged 10 feet 7 inches in length, while where ground bone was used at the rate of 1 pound per plant the increase was much greater, these plants averaging 22 feet 7 inches in length (Pl. I, fig. 1). Since fine ground bone contains more than 22 per cent of phosphoric acid, while acid phosphate contains only about 15 per cent, the greater increase in plants treated with 1 pound of bone is perhaps accounted for by the fact that these plants each received a much larger amount of phosphoric acid. The presence of approximately 4 per cent of nitrogen in the bone may also have had a beneficial effect, but by referring to division 2, row No. 11, it will be seen that nitrogen added to the acid phosphate in the form of sulphate of ammonia produced no beneficial results.

The effect of phosphoric acid and potash without nitrogen was not tested.

The complete fertilizer used in division 3, which contained only about 0.26 pound acid phosphate per plant, produced greater growth than did 1 pound of acid phosphate alone. This would seem to indicate that some of the benefits following the use of the mixed fertilizer must have been due to either the potash or the nitrogen, or to both.

One of the most striking features of these tests as a whole was the complete failure of most of the unfertilized plants, many of them having failed even to live.

It is fair to conclude from the above that for the successful growing of crops phosphoric acid in liberal amount must be applied to the type of soil used. Further experiments are now under way to determine more accurately the requirements in the way of potash and nitrogen in combination with the necessary phosphoric acid.

Pruning.—On January 30 and 31 all the vines on the experimental plats were pruned by cutting back, leaving about two buds of the preceding season's growth. Some bleeding followed, a more or less common occurrence in this climate where there is no cold weather to arrest the flow of sap. To give the vines the best possible chance, grafting wax was applied on March 1 to each of the wounds.

Trellising.—In Hawaii practically the only type of support for grapevines is the overhead arbor trellis adopted by the early Portuguese growers, this being the type with which they were familiar in Madeira, where the grapes of Hawaii originated. It has not been determined whether any of the other systems of trellising are better adapted to local conditions. The arbor system, while it has certain advantages, has perhaps greater disadvantages, such as its expensiveness and the impossibility of standing erect under the average trellis or of cultivating with horse or mule. It was decided to try what is usually known as the Munson 3-wire trough trellis, the cost of materials for which is little more than a third that of the usual overhead arbor of wood. The Munson trellis consists essentially of three wires separated by cross arms on upright posts, the central wire being a few inches lower than the other two. The vines are trained along this central wire, and the new growth each season falls naturally over the outer wires. The upright posts, which are placed twice, or in some cases three times, as far apart as the plants, according to their arrangement, may be 20 to 24 feet apart, and it is necessary that the end posts be well braced to prevent their being pulled over by the strain. The wire used on the trellis which was constructed during April, 1917, was No. 10 for the center of the trough and No. 12 for the outside.

Control of Japanese beetle (*Adoretus umbrosus*).—The Japanese beetle is one of the most important insect pests of grapes, particularly where they are grown in very restricted areas. With only a few plants in a home garden, these beetles will frequently consume the entire foliage. Many means have been employed in the attempt to control this insect, not only on grapes but on the very large variety of plants upon which it feeds.

The method which has perhaps proved most effective among the small growers of grapes in and about Honolulu has been hand picking at night when the insects are at work on the foliage and can be found with lanterns. The adult beetles feed exclusively at night, the daylight hours being spent beneath the surface of the soil or in other hiding places away from the light. Hand picking is tedious and expensive but is often done on small areas where the pests are not too numerous. A fungus disease has proved a decided factor in the control of this beetle in rainy sections and also during the rainy season in all parts of the islands. The use of arsenical poison for the control of this pest has not found great favor, but as no thorough tests of its use have been reported the station decided to undertake some systematic trials on grapevines growing in cans. These have given very promising results which are reported upon by James H. Cowan, as follows:

> Although few definite data have yet been obtained concerning the protection of grapevines in the vineyard against the attacks of the Japanese beetle, an experiment on a very small scale was carried on at this station during the early part of the year 1916 with encouraging results. Seventy grapevines, all of the same variety and of the same age and size, were used. These vines were grown in tin cans and were so arranged as to form seven rows equally distant one from the other, the distance of the plants in the rows being equal to the distance of the plants between the rows. The rows were labeled A, B, C, D, E, F, and G, reading from left to right. Row A was sprayed with an arsenical spray consisting of 1 pound of a powdered form of arsenate of lead to 5 gallons of water. Row B was left unsprayed as a check. Row C was sprayed with a proprietary brand of arsenate of lead that is sold in the paste form and is claimed to be very adhesive. This was used in the proportion of 1 pound to 10 gallons of water. Row D was left unsprayed as a second check. Row E was sprayed with another brand of arsenate of lead also sold in the paste form, and this was used in the proportion of 1 pound to 10 gallons of water. Row F was a third check, and row G was sprayed with the same brand of arsenate of lead as was used in row A only in the proportion of 1 pound to 10 gallons of water. Plate I, figure 2, shows an average plant of each row except row A, where the results were not distinguishable from those of row E. The photograph was taken six days after the application of the sprays. On the morning following the day on which the plants were sprayed almost every unsprayed plant had been slightly riddled, while those which had been sprayed were untouched. The rain during the second night almost completely washed off the spray on rows A and G. Observations during the evenings also indicated that there were fewer beetles at work during the rainy evening than on the following dry nights. A few dead beetles were found in rows C and E on the third, fourth, and fifth mornings. When the photograph was taken on the sixth morning the plants in row C were the least eaten and the spray on these appeared to be as much in evidence as on the day when it had been applied. Row E was next in degree of protection, the plants on an average being nearly as well protected as those in row C, but the spray was beginning to lose its adhesiveness. The plants in rows A and G were at this time eaten about 25 per cent more than those in C, due to the fact that they had lost about 90 per cent of the spray.

It would appear that a very high degree of protection from these insects can be given to grapevines by the use of rather strong doses of arsenical sprays. One of the most important features of a spray for this purpose in a tropical country with frequent showers is the adhesiveness of the preparation.

AVOCADO INVESTIGATIONS.

There are now in the plant houses and ready for orchard planting several hybrid avocados, resulting from the crossing of an unnamed but very promising seedling of Guatemalan type (avocado series No. 160) with pollen from four varieties of West Indian avocados, some of which are very rich but are not well protected by a tough or hard rind. The Guatemalan type is characterized by a thick, woody, or corky rind which gives it ample protection from external injury, but fruits of this type are not equal in richness to some of the varieties used as pollen parents. The West Indian varieties tend to fruit in the summer and early autumn, while the Guatemalan, although variable in season, usually mature between November and March. If a winter-fruiting avocado having high oil content and excellence of flavor, combined with a protective rind, can be originated, it will be a genuine acquisition, but a summer-fruiting variety with a tough rind would be of somewhat less value. It must be remembered, however, that toughness of rind is not the only factor entering into good keeping qualities, as in some fruits there is a breaking down of the tissues from within entirely apart from any external injury.

The collection and description of varieties and their propagation have been continued by Mr. Cowan. About 30 seedlings of local origin have been described and are being made the subject of further investigation. The records consist of descriptions of the fruits, outline drawings with preserved specimens when possible, and all available data regarding the trees. As all varieties are being scrutinized as carefully as possible before being listed, it is not to be expected that many of the large number of sorts under test in Hawaii, California, Florida, and elsewhere will prove commercially successful. Although there is no desire to lengthen the list of varieties for general planting in this or other avocado-growing countries, it is thought that there can hardly be too many promising forms under trial, from which, however, an active process of elimination must sift all but a very few which reach the highest commercial standard.

There have been introduced during the year through the kindness of Joseph Sexton, of Goleta, Cal., seven varieties attracting much attention in that State, where avocado growing is rapidly developing into an important industry. These varieties, with the Hawaii Station division of horticulture accession numbers, are as follows: Taft (No. 3834), Atlixco (No. 3835), White (No. 3836), Blakeman (No. 3837), Colima (No. 3838), Lyon (No. 3839), El Fuerte (No. 3840).

MISCELLANEOUS BREEDING INVESTIGATIONS.

There are now in the plant houses several young mango trees believed to have been produced by cross-pollination. These crosses were made by Valentine S. Holt, formerly assistant horticulturist, who states that the flowers were all carefully protected from any accidental pollination. It is hoped with some confidence that they are not the result of multiple germs or adventitious growths, as none of them has been observed to send up more than one stem from a seed. The crosses include Scott×Pirie, Kavasji-Patel×Pirie, Java×Pirie, Paheri×Pirie, Pirie×Alphonse, and an unnamed variety×Pirie.

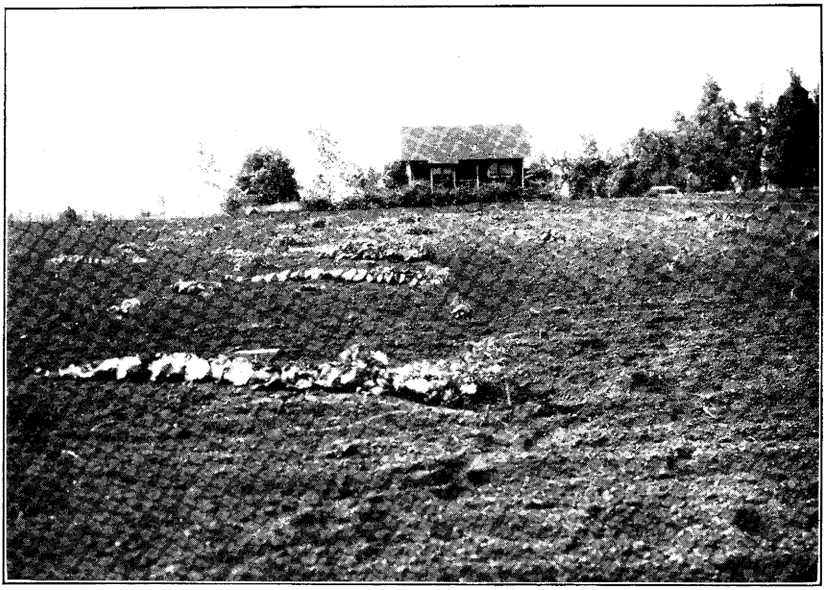

FIG. 1.—EFFECT OF FERTILIZERS ON GROWTH OF GRAPEVINES.

Central row received ground bone; checks on either side, nothing.

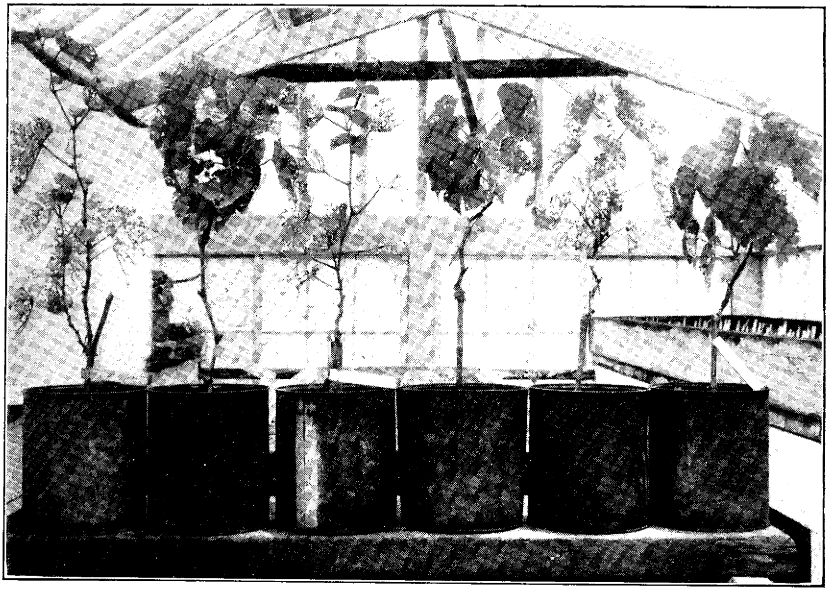

FIG. 2.—EFFECT OF ARSENATE OF LEAD ON CONTROL OF JAPANESE BEETLE.

Alternate vines unsprayed.

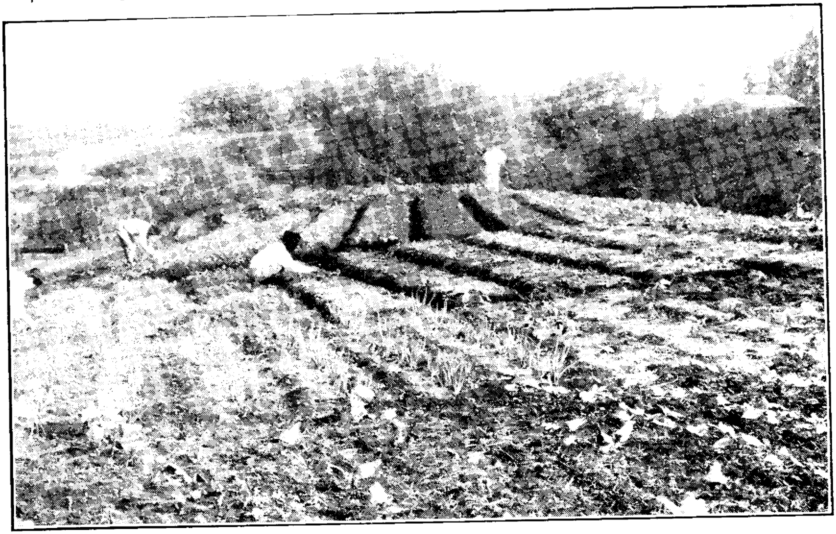

FIG. 1.—WASTE LAND CLEARED AND TENDED BY STATION EMPLOYEES AFTER OFFICE HOURS.

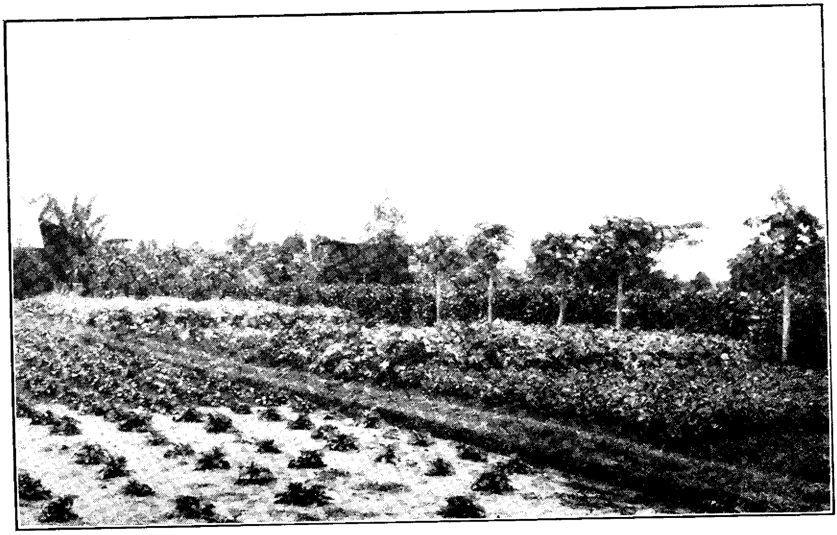

FIG. 2.—FRONT YARD GARDEN NEAR HONOLULU.

EMERGENCY GARDENS.

In connection with papaya breeding there is little to report at this time. It is interesting to note that the excellence of flavor which characterized one of the original selections has now been transmitted through three generations in a large proportion of the offspring. There is also an encouraging ratio of bearing to nonbearing trees.

Other breeding work under way includes the crossing of certain varieties of tomatoes in an effort to secure a strain combining sufficient size with resistance to the melon fly (*Dacus cucurbitæ*), which is a great menace to tomato growing in Hawaii. Some attempts have also been made to hybridize certain species of Eugenia.

CACAO CULTIVATION IN HAWAII.

In March, 1917, the Legislature of the Territory of Hawaii, then in session, requested the station to supply a statement on the possibilities of cacao growing in Hawaii. The following notes on the subject were prepared, including data on the history of this tree in these islands and, since they may serve as a record to date and also as a reply to such inquiries which arise from time to time, they are incorporated here.

Climatic and soil requirements.—In order to get a clear understanding of the possibilities and limitations of cacao culture in Hawaii, it is necessary to consider the natural requirements of this crop. Cacao is strictly a tropical plant, being injured by climates in which the temperature repeatedly falls below 60° F., although an occasional fall of this kind is not prohibitive to its growth. Liberal moisture in the soil is imperative, and in practice this is usually supplied by rain, irrigation not often being resorted to. It is difficult to give any figures adequately expressing its requirements in the way of soil moisture, since so much depends upon the distribution of the rainfall through the year and the water-holding capacity of the soil. Most of the successful cacao-growing countries have a rainfall of more than 70 inches per year, which, however, would be insufficient if it were unevenely distributed or if the trees grew in soils retaining their moisture badly. On the other hand, excessive rain at harvest interferes with the curing of the beans. Another prerequisite is shelter from winds, strong winds being exceedingly destructive to the interests of the planter.

Trials of cacao in Hawaii.—The late Dr. Hillebrand, who lived in Hawaii during the 20 years preceding 1871, probably introduced the cacao tree in Hawaii, a specimen still surviving on the property planted by him on Nuuanu Avenue, Honolulu, and now owned by Mrs. Mary E. Foster. Other trees of comparatively early introduction or planting are to be found in various parts of the islands, notably in and about Hilo, trees about Honolulu having been less successful. Some years ago there were a number of trees at Ahuimanu ranch on windward Oahu, some of which are probably still producing. The promise of success given by the trees in the vicinity of Hilo led the station at one time to introduce more plants for trial in the Hilo district, an experiment being undertaken some years ago in cooperation with the Hilo Boarding School, which had to be given up on account of lack of funds. A few of the trees, however, which have survived and have been cared for by the school appear to be in a healthy condition. They are reported to yield fairly well and the pods which have been received at the station are good specimens.

Prospects in Hawaii.—The tree begins to bear fruit about the fourth year after planting, and increases in production for several years. The yield of an established cacao plantation runs from 300 to 600 pounds per acre. The prices of the different grades at the present time range from $11 to $16 per hundredweight, the latter being commanded by the product of only the finest varieties, which, in turn, do not yield the maximum crop. The present high prices are not likely to continue, and for calculating returns, $10 to $14 per hundredweight would be as high as it would be safe to expect, which would make the gross receipts per acre run from $30 to $84 per year.

As curing cacao is a process which does not require elaborate machinery or expensive equipment, the crop in this respect is well adapted to the use of small growers who may be quite widely separated. In addition the beans, when cured, are not a highly perishable product. This makes it possible to grow cacao on comparatively cheap lands at considerable distances from the world's markets and with the cheap labor so prevalent in most tropical countries. Hawaii, therefore, would have to meet strong competition in marketing the raw product. By reason of its nearness to markets and its good transportation facilities, Hawaii could counterbalance this disadvantage by entering the field of manufacture—a thing not yet attempted generally by countries far from the consumer.

The data in hand indicate that any attempts to establish cacao growing as an industry in Hawaii should be confined to localities near sea level, and only those sheltered places which are warm and moist are to be considered. Sheltered spots in Hilo and Puna, in general, offer the best locations for further trials. The Hana coast of Maui presents some advantages.

Through the cooperation of the Hilo Boarding School, the station will soon be able to secure a limited supply of seed, and will gladly assist any who wish to make further trials of cacao in promising localities by supplying such plants as may be available.

Methods of cultivation.—The cacao tree grows to a height of 15 to 25 feet and produces its fruit or pods on the trunk and main branches. The tree is propagated from seeds, which must be planted while fresh, as they retain their viability for only a short time in the pod and perish almost immediately if removed from the pod. These seeds are usually planted in nurseries, and the young plants removed to their permanent location when about six months old. Some growers prefer to stake off the plantation and plant the seeds by the stakes, which represent the permanent location of the trees. Though grafting and budding have not been generally practiced with cacao, the tree is adapted to this method of propagation, which is now receiving some attention as a means of establishing plantations of high yield and of greater uniformity in product. Cacao is generally grown with shade, preferably leguminous trees, which also furnish protection from wind, a more important function than that of giving shade. Some temporary shade is usually provided by rapidly growing plants, such as bananas, until the permanent trees are well grown.

The ripe pods, from 6 to 12 inches in length, are picked by means of a tool not unlike a reaping hook. They contain about 30 seeds or "beans," surrounded by a mucilaginous substance, which are removed promptly and placed in heaps or in vats to ferment. The heaps are turned over at intervals during fermentation, the process being completed in from 2 to 10 days according to the conditions. The seeds or "beans" are then washed and are exposed to the sun for a short time each day until dry to preserve their plumpness, which would be lost if the drying were completed immediately by one exposure. These dried beans—the product from which cocoa and chocolate are made—are then ready to be bagged and shipped to market. Usually the manufacturing of chocolate and cocoa is not carried on in the countries where the cacao is produced, doubtless because the beans are so much more easily shipped.

FOOD-PRODUCTION WORK.

There was a very marked increase of interest in all branches of food production during the year. In encouraging and establishing such work the horticultural division has taken an active part in every way possible. The movement was given a strong impetus by the school garden and home garden contests conducted by the Honolulu Star-Bulletin. As a member of the board of judges of these contests, the horticulturist came into close contact with the movement on all parts of the island of Oahu, all the school gardens having been visited at least twice and many of the home gardens on one or more occasions. The contests had a very marked influence in stimulating interest in the production of vegetables, the children conducting gardens not only in the school yards and those surrounding their homes but in many cases on ground nearly a mile away, traveling back and forth on foot to keep their growing crops in good condition. The influence extended to neighboring homes and as a result of the presence of some successful pupil's garden in the vicinity, it has been common to find gardens springing up about homes which have no children at school.

All this work was a fitting preparation for the emergency food campaign which started vigorously in the latter part of the third quarter of the year and continues at the present time. The need for larger national production is being emphasized here, with special reference to the undesirably large importation of the foodstuffs which are consumed in these islands. Vegetable gardens have sprung up everywhere and larger plantings of the staple vegetables such as sweet potatoes, Irish potatoes, and beans are in evidence in many places. (See Pl. II, figs. 1 and 2.) The division of horticulture has been able to render some assistance in this work by means of addresses before various organizations desirous of acquiring knowledge of methods of growing food crops and a short series of lectures given to the Women's Navy League.

It was also the privilege of the division to cooperate with the other branches of the station, especially the extension division, in the preparation of a planting chart, giving in very condensed form essential data regarding all the vegetable crops that may be grown in Hawaii. In addition to requests for information which it was possible to furnish through letters or publications to groups of individuals and organizations, many inquiries were received which necessitated personal visits to lands under consideration for food production, as those of the Boy Scouts and others who contemplated planting on a much larger scale. The volume of inquiries by telephone and letter also was much greater than usual during this period, a fact indicating the very large increase of interest in the growing of crops in Hawaii.

There has also been a great demand for plants, and the station has distributed in small numbers to each individual such plants as were available and which could be expected to give an early return. These distributions have included many hundreds of plants of tomatoes, papayas, roselle, sweet potatoes, etc.

BULLETINS FOR PUBLICATION.

The manuscript for a bulletin on the Litchi in Hawaii was submitted for publication in the early part of the year.[1] Another manuscript relating to the cultivation of the banana as a source of food supply is in process of preparation.

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[1] Hawaii Sta. Bul. 44 (1917).

EXTENSION WORK.

In addition to the extension activities mentioned elsewhere, the horticulturist, with J. B. Thompson, superintendent in charge of the Glenwood substation, spent about two weeks in the interests of this work on Hawaii, chiefly in Kona, during which time James H. Cowan, of the horticultural division, took temporary charge of Mr. Thompson's work at Glenwood. The horticulturist also attended the Maui County Fair, judging horticultural products and also assisting in connection with the experiment station exhibit. Later in the year another trip was made to Maui partly in the interests of extension work and partly in connection with pineapple investigations.

ADDITIONS TO EQUIPMENT.

No extensive additions were made to the equipment. A steam sterilizing plant was installed for the treatment of soils for use in the greenhouses and propagating yards. Two overhead systems of irrigation are being tested in these yards. As opportunity offers, a collection of specimens of fruits in preservative fluids in museum jars is being made by Mr. Cowan.

REPORT OF THE CHEMICAL DIVISION.

By MAXWELL O. JOHNSON.

During the past year the work of the chemical division has been continued largely along the lines indicated in the report for 1916. The problem of successfully growing pineapples on the highly manganiferous soils of Hawaii appears to have been solved commercially by spraying the plants with solutions of iron sulphate. Further investigations are being made of the scientific aspects of this problem. The work on the wilt of pineapples has been continued and a number of experiments laid out. Some work has been done on the fertilizing of bananas, rice, and pineapples. Preliminary experiments have been made on the drying of food crops. As the assistant chemist has been on furlough during the entire year the work of the chemical division has been necessarily somewhat curtailed.

INVESTIGATIONS ON THE MANGANIFEROUS SOILS OF HAWAII.

The most important work of the past year was the practical development of the iron sulphate spraying treatment for overcoming the very injurious effects of the highly manganiferous soils on pineapples. A preliminary announcement of results was given in the annual report for 1916. Further results have more than justified expectations. A popular discussion of the results secured in field experiments by the iron sulphate spray and practical advice as to the treatment of manganiferous soils were issued during the past fiscal year in a press bulletin of this station.[1] The application of small quantities of an approximately 8 per cent solution of iron sulphate (32 pounds of copperas to 50 gallons of water) in the form of a fine mist appeared to be most effective and economical. An article on the scientific phases of this problem was also published during the past fiscal year.[2] In order to clear up some doubtful technical points, further investigations of the effects of manganese in a series of water cultures have been started which promise to throw some light on this question as well as on the relation of manganese and iron. The results will be further confirmed by pot cultures.

As a result of these experiments all the Hawaiian pineapple plantations have now adopted the sulphate of iron spray for pineapples on manganiferous soils. Statements recently secured from the larger companies show that 5,094 acres of pineapples are being sprayed by them at the present time. In addition to this acreage, there are in the aggregate considerable areas belonging to smaller growers which are being sprayed, and also much new manganese land is being put into pineapples at the present time, largely by reason of the fact that a practical means of overcoming the manganese difficulty has been discovered. The readiness with which this new procedure has been adopted is evidence of its practical value.

During January, 1917, a trip was made to the island of Lanai, at present devoted to ranching, to investigate its possibilities for pineapple production. The chief agricultural lands of this island consist of about 20,000 acres lying in a saucerlike depression at an altitude of about 1,000 feet. The soil contains considerable manganese dioxid and on it small plantings of pineapple show the typical "manganese yellows." It is very probable that if this large area of potential pineapple land is ever brought under cultivation for that crop the iron-sulphate spray will be necessary for profitable results.

INVESTIGATIONS CONCERNING THE PINEAPPLE WILT.

The investigations on the Kauai wilt of pineapples were continued. The wilting is more widespread than was at first thought, and it is a very serious problem to the pineapple growers on the windward side of Oahu and also on the mauka (upland) soils on the leeward side of the Koolau Range. The dying back of pineapples on the island of Maui also seems to be a form of wilt, but the collapse of the plants is less rapid.

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[1] Hawaii Sta. Press Bul. 51 (1916).

[2] Johnson, M. O. Manganese as a cause of the depression in the assimilation of iron by pineapple plants. Jour. Indus. and Engin. Chem., 9 (1917), No. 1, pp. 47–49.

From present evidence regarding the wilt, it appears to be a root rot partly due to lack of drainage and partly to high acidity or sourness of the soil, the more serious form being associated with the yellow or yellowish-brown soil derived from volcanic ash. A number of field experiments have been laid out in an effort to overcome this trouble, but the plants have not yet matured sufficiently to permit definite conclusions as to the value of the various remedies under trial.

SPRAYING OF FERTILIZER ON RICE, BANANAS, AND PINEAPPLES.

The success met with in spraying with iron-sulphate solutions has led to spraying experiments with other fertilizers. The maintenance of a continuous food supply to the plant by spraying with a small amount of fertilizer at frequent intervals would appear to be a more logical method of fertilization than the application of a large amount of fertilizer before planting, as in the latter case the fertilizer is more subject to loss by leaching and by fixation by the soil. Preliminary cooperative experiments are being conducted with bananas, rice, and pineapples, the results of which will be published later.

CHEMICAL STUDIES OF LEGUMES AS GREEN MANURES.

In connection with the project on the chemical study of legumes as green manures, which was completed during the fiscal year 1916 by Miss Alice R. Thompson, assistant chemist, numerous analyses were made of the nitrogen content of a number of varieties of legumes grown under identical conditions. These results have been recast and with the aid of field data furnished by C. A. Sahr, assistant agronomist, as to the yields of the legume varieties, it has been possible to make a general comparison of the relative efficiency of the different varieties of legumes in furnishing nitrogen to the soil. The results of this work were issued during the past fiscal year as a press bulletin of this station.[1]

THE DRYING OF FOOD PRODUCTS.

As the national food shortage during the present year has rendered any method of food preservation important, the station has undertaken experiments on the drying of food products under Hawaiian conditions. With the strong trade winds and the many relatively clear days, the simplest and most economical method of food preservation appears to be drying by the sun. Preliminary experiments having shown that cassava, taro, sweet potato, and other food products can be dried very easily by this method, a small drier has been built to secure practical data on the problem.

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[1] Hawaii Sta. Press Bul. 52 (1917).

REPORT OF THE EXTENSION DIVISION.

By F. G. Krauss.

The extension division of the station is now in its third year, and it is believed that the services thus far rendered to the farmers of Hawaii have fully justified its establishment. The research work of an experiment station is only completed when its findings are expressed in terms which the farmer can put to practical use. It is the function of the extension division to interpret by actual demonstrations, or other acceptable methods, technical and often obscure work not only of State experiment stations but of the United States Department of Agriculture and other agencies not always accessible to the lay farmer.

DEMONSTRATION AND ADVISORY WORK.

Whenever it has been posssible, and to the full extent of its resources, the extension division has arranged cooperative experiments in testing new and improved crops, better cultural, feeding, and marketing methods, cost accounting systems, and in such other work as modern agricultural development has seemed to warrant. On the whole a very satisfactory response has come from both small and large farmers in their willingness to try out new crops and better cultural methods. This is especially true in the matter of forage crops, to which the extension division has given particular attention. At the substation and demonstration farm at Haiku, Maui, tests are made on a field scale of all promising crops sent out by the Hawaii Experiment Station and by the United States Department of Agriculture, as well as those collected from other sources (Pl. III, fig. 1). Different cultural methods (Pl. III, fig. 2), including green manuring and fertilizing, intercropping, and crop rotations have been tested and comparisons made of seasons for planting, rates of seeding, methods of selective breeding and harvesting and curing crops, and in a number of cases, their effects when fed to live stock.

To the extent of its means, modern farm implements and machinery have been added to the equipment of the substation.

The agricultural community and all interested persons have been invited to visit the extension-division farms, and many have responded. It is estimated that between four and five hundred visitors came to the substation at Haiku during the past year, which, in view of the limited number of persons engaged in diversified farming on Maui, is thought to be of considerable importance. The superintendent is frequently called into consultation by the farmers, and makes many excursions to give advice of an agricultural nature. The correspondence is also large. Occasional contributions are made to the press, a total of some 30 articles on agricultural subjects having been prepared during the past year, besides several manuscripts for bulletins.

Large quantities of seeds and plants have been distributed throughout the Territory, most of which were grown at the substation at Haiku. Besides stimulating the production of new and better crops, this distribution is expected to lead to the accumulation of many important data, as applicants have been requested to report upon the results of their experiments. In so far as it has been found feasible the farm equipment of the substation, such as seeders, thrashing outfits, etc., has been made available to the community.

Possibly the most important feature of the work of the year has been the close cooperation between the extension division and specialists in the various branches of agriculture. This has permitted the reference of special problems to those most capable of their solution. All departments of the Federal experiment station have rendered valuable aid to individual farmers as well as to the extension division.

FORAGE AND GREEN MANURING CROPS.

Recognizing early in its work the importance of local production of at least a part of the expensive feedstuffs hitherto imported from the mainland, the extension division set about growing on a field scale the more promising forage crops, both at the demonstration farm at Haiku and in cooperation with farmers. The progress of this work up to last year was reported in the last annual report of the station. During the fall of 1916 and spring of 1917 about 40 acres was devoted to leguminous and nonleguminous forage crops. The legumes include 12 varieties of cowpeas, 4 of velvet beans, 2 of peanuts, 6 of soy beans, and 4 each of alfalfa, pigeon peas (*Cajanus indicus*), and jack beans (*Canavali ensiformis*).

A dozen or more of the above varieties have now found a permanent place in Hawaiian agriculture. Among the most prominent are the Brabham and Iron varieties of cowpeas for forage and green manuring purposes, the Groit and Taylor varieties for seed, and the Whippoorwill as a general-purpose pea. While only fractional acre plats of the above were grown in the trial grounds three years ago, several hundred acres was planted in the Haiku district this spring. Among the velvet beans the Brazilian variety is now taking the lead, and all available seed has been planted. Of the half dozen varieties of peanuts grown several years ago, the Improved Valencia has become standard. The jack bean and pigeon pea are well established. Sunn hemp, owing to the expense of harvesting the seed, is not as promising as it formerly seemed to be, although it is still of promise for green manuring and as a possible fiber plant. Soy beans give uncertain results, but the great value of the crop justifies a continuation of experiments with them. The alfalfas on the raw uplands do not thrive, but of some 10 varieties under test the smooth Peruvian and hairy Peruvian varieties give the greatest promise. All varieties have responded to liberal manuring and fertilizing with phosphate, but liming and artificial inoculation appear to have been without beneficial effects.

Among the grasses, the Japanese cane is giving excellent results, and large acreages are being planted (Pl. III, fig. 1). The same to a somewhat less extent is also true of Sudan grass and Australian grass (*Paspalum dilatatum*). Of these three grasses the Japanese cane and the Paspalum are preferable, mainly because of the susceptibility of Sudan to rust, especially in moist locations. However, Paspalum is chiefly pasture grass.

Corn culture, as in the past, has received much attention because of the importance of the grain. The production of 100 bushels, 5,680 pounds of shelled grain, from an acre has set a new mark for Hawaii. When it is taken into account that the land upon which this crop was grown produced only about 35 bushels in its virgin state, the importance of the agricultural methods adopted will be better appreciated. The corn grown was an early maturing yellow dent variety developed by the substation at Haiku from Funk's Ninety Day, Reid's Yellow Dent, and Gold Standard Leaming. The soil, a medium loam, had received some 60 tons of green manure in the course of three years, and at seeding 500 pounds of high-grade fertilizer was drilled into the rows, which were spaced 30 inches apart. The season was fairly favorable, there being ample moisture, but strong winds prevailed during a large part of the growing period. In an adjacent plat, with all other conditions identical except the spacing, the rows being 60 inches apart, slightly less than half the yield of the 30-inch rows was obtained. The theory is that, there being optimum fertility and moisture to develop the closely planted crop, the close planting provided better protection against the strong winds than did the wide planting. The present spring crop just being harvested, following a dry season, is yielding at the rate of about 70 bushels per acre with rows spaced 60 inches apart. This corn is intercropped with sweet potatoes and received no fertilizer other than the green manure referred to above. The present price of small yellow dent corn in the Honolulu market is $73 to $78 per ton. It will thus be seen that a 70-bushel, or 2-ton, corn crop is profitable farming, although the cost of production per acre approaches $75.

Numerous varieties of grain sorghums and millets, together with buckwheat and sunflower seed, were tested with a view to determining the most profitable sorts to grow for chicken feed. A number of varieties found promising will be given further trial. An acre plat of sunflowers produced 700 pounds of clean seed, which, at $3 per 100, was grown at a loss, but it should be noted that the land upon which this yield was obtained failed to produce ear corn and that certainly no other crop would have produced as favorable results under the conditions as did the sunflowers.

Eighteen varieties of cereals, including wheat, oats, barley, and rye, were tested in cooperation with the station. The ryes proved totally unsuited to conditions. The other three grains set seed and are worthy of further trial. As catch crops for hay, especially during the present period of high prices of feeds, it seems quite probable that the cereals might be made profitable.

White and sweet potatoes continue to receive much attention at the substation and demonstration farm at Haiku. Of the eight varieties of Irish potatoes with which work was started three years ago, a superior strain of Bliss's Triumph has been developed, and this now appears to be firmly established in the Kula potato district. The experiments and demonstrations in spraying potatoes with Bordeaux mixture, carried on in cooperation with the pathologist of the station, have given definitely favorable results on the summer crop in the Makawao district, over 50 per cent increase in yields having resulted from spraying alone. At present prices this increased production is valued at over $100 per acre. Since the Kula and Makawao potato is one of the three most important staples of the district, a vigorous spraying campaign will be undertaken in connection with the fall potato crop. A project is also being planned for cooperative experiments in better cultural methods, including the introduction of better seed.

Since the establishment of headquarters for the extension division at Haiku, Maui, one of the important centers of the pineapple industry, much cultural work has been done with this crop. During the past year the importance of planting only selected plants, whether crowns, slips, or shoots, has been fully demonstrated. As plants have been in great demand in recent years, planters have been inclined to plant any and all available stock regardless of its source or quality, but the low vitality of the resulting progeny has been a most potent factor, though not the only one, in producing the many ills of the pineapple grower. Fortunately, growers generally are recognizing the truth of this contention, which is readily demonstrated.

Another important practice inaugurated by the extension division is that of subsoiling between the pineapple rows and maintaining practically a flat culture rather than the deep furrowing and high hilling commonly employed in the wetter districts. The method used at the substation is to subsoil between the rows as soon as the plants have become established and to follow with a middle burster, which throws out the soil to either side, many weeds being destroyed by this operation. In a week or 10 days the soil is thrown back into the furrow by the use of a special 15-tooth cultivator having the tooth bars slightly curved so as to leave the space between the rows a little dished. The subsoiling, middle bursting, and cultivation is repeated four times during the first year's growth, after which it is no longer possible to work between the rows. As a result of this practice, the soil is broken up to a depth of approximately 18 inches between the rows without bringing the subsoil to the surface, good drainage is secured, and a deep, loose foraging ground provided for future root development, and this at a time when the plant is in greatest need of expansion. By the old method, the plants were left perched on hard, baked ridges, with the possibility of fullest development only in very favorable seasons.

Drainage experiments conducted in porcelain pots as well as in the field indicate strongly that many pineapple troubles are due to a stagnant condition of the soil, as regards both air and water, a conclusion which the results from the subsoiling and mulching experiments tend to confirm.

Fertilizer experiments carried on for several years have thus far given results too inconclusive to warrant a report other than that reverted phosphate appears to be the most beneficial treatment yet tried. A series of liming experiments in cooperation with the station chemist is now under way in the Haiku district.

As a valuable adjunct to diversified farming on the islands, the extension division is furthering the swine industry by maintaining a small herd of registered Berkshire swine at the substation at Haiku, where it is planned to develop a modern pig plant for demonstration purposes. Farm-grown feeds are used in large part. A portable hog cot, with built-in self-feeder devised by the substation, has been widely copied by the hog raisers on the island of Maui and elsewhere, while a successful demonstration in home ham and bacon making just completed has already stimulated enterprise along the line of a more rational farming than has hitherto been practiced by the small farmer of Hawaii.

An important advance in agricultural development was made when Hawaii and Maui Counties inaugurated their annual agricultural fairs. Maui County's first fair, held November 30 to December 2, 1916, was actively supported by the extension division, which not only fostered the enterprise, but gave exhibits and demonstrations.

Four collaborators are maintained on the different islands whose duty it is to render "first aid" in their respective districts. The superintendent keeps in touch with these by occasional visits and

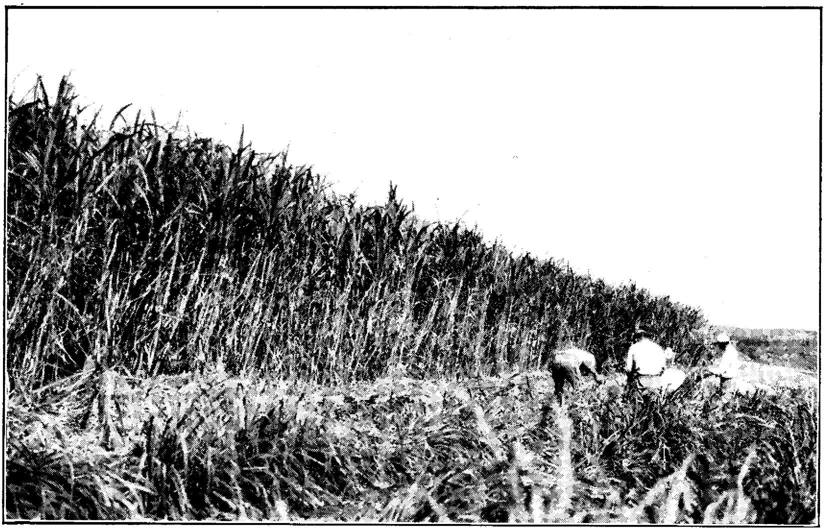

FIG. 1.—JAPANESE CANE AS A FORAGE CROP AT HAIKU.

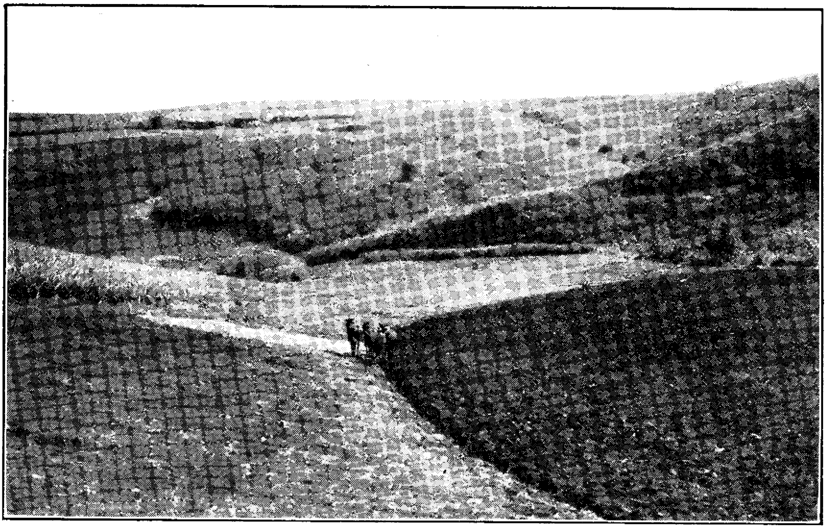

FIG. 2.—EXPERIMENTAL TILLAGE FIELD AT HAIKU.

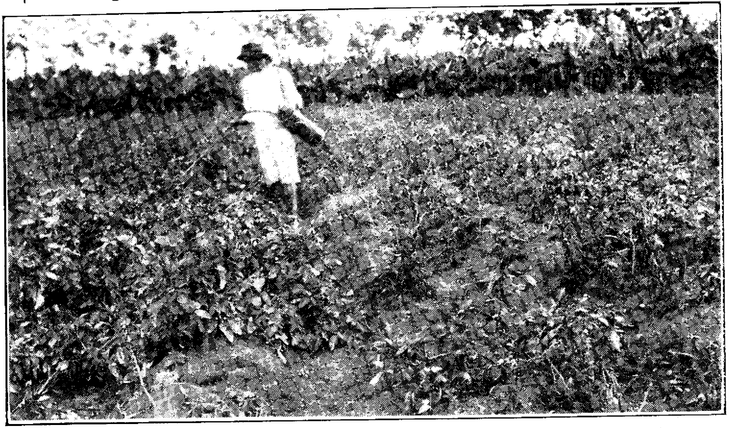

FIG. 1.—ROWS AT LEFT SPRAYED ONCE WITH BORDEAUX MIXTURE, ROWS IN CENTER NOT SPRAYED.

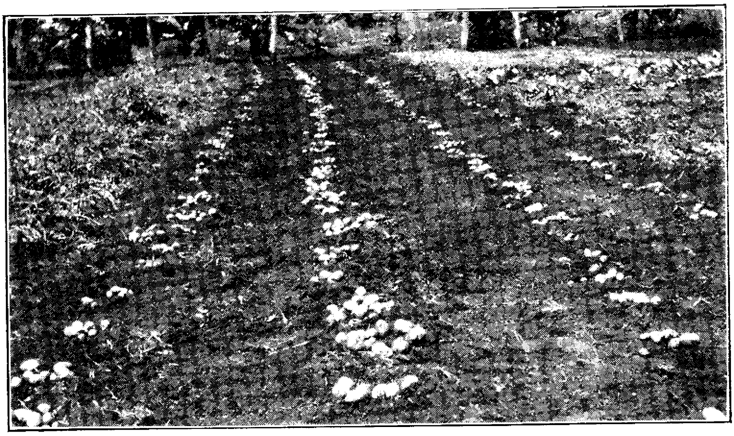

FIG. 2.—CENTER ROWS SPRAYED, OUTSIDE ROWS NOT SPRAYED.

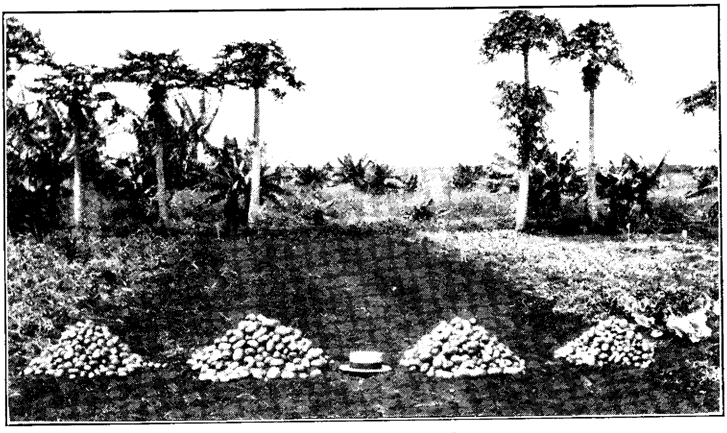

FIG. 3.—POTATOES PILED FOR COMPARISON.

POTATO SPRAYING EXPERIMENTS.

correspondence. The newly formed Territorial Food Commission supplements the work of the extension division, forming an important link between the producer and consumer, and the several Government agencies work in close cooperation for the development of a better agriculture for Hawaii.

UTILIZATION OF LOCALLY GROWN FOOD CROPS.

There are in Hawaii a great number of races and nationalities which have brought with them and still maintain a preference for the food used in the countries from which they came, most of which has to be imported from the country in question. Greater utilization of the food crops that are or can be grown in Hawaii would, it is felt, do much toward overcoming the tendency to import such a great proportion of locally used foodstuffs. With a view to increasing the utilization of local foods, the extension division, with the cooperation of the other branches of the station and the wives of various members of the station staff, has done active work in emphasizing the various methods by which the native and introduced food crops can be prepared so that they can practically replace the imported articles. At both the county fairs held during the year numerous samples of preserved native fruits were exhibited to show that they constituted an excellent substitute for the imported product. Through various women's organizations, the substitution of locally available food crops for similar imported ones has been actively fostered both by actual demonstrations at fairs and special meetings and by articles in agricultural and home-economics sections of the local papers.

REPORT OF THE DIVISION OF PLANT PATHOLOGY.

By C. W. CARPENTER.

During the past year the plant pathology division was established and a laboratory equipped in a suitable manner for the investigation of plant diseases and the study of fungus and bacterial organisms. The office and laboratory formerly occupied by the division of entomology in the main office building were used with but slight changes. Owing to the fact that this building is not fireproof, it was considered inadvisable to install gas. To meet the needs of the new division, one of the small insectary buildings was moved to a position in the rear of the main building and fitted up as a laboratory kitchen, and though rather small this furnishes a complete one-room laboratory suitable for the preparation of culture media and for other operations requiring gas. In equipping the pathological laboratory, expensive equipment of a specialized nature has been avoided and will be until the need of such apparatus shall have presented itself.

At the inception of the work of the new division, it seemed desirable to become familiar with Hawaiian agricultural conditions as quickly as possible. To this end the problems which presented themselves were taken up in turn for a preliminary investigation with no idea of making an exhaustive study at the time. Every opportunity has been utilized to get in touch with the problems in the field where observations could be made at first hand.

The experience of the year shows that there is in Hawaii a fertile field for pathological investigations and that there are a number of questions of sufficient economic importance to justify critical study. There is also need of considerable extension work along the lines of food conservation through disease and insect control. This phase of the work has been receiving a major portion of the time of the division since the announcement of a threatened national shortage of food. Circular letters have been prepared for correspondents concerning the preparation of Bordeaux mixture and other sprays, disinfecting dips for seed potatoes, poison baits for cutworms, and the fumigation of stored products. To aid further in the conservation of food crops, an emergency bulletin of a popular nature on Methods of Combating Garden Pests has been submitted.[1]

A number of plant diseases have been observed during the past year and in some cases the causal organism has been cultured and identified. In most cases the organism has not been subjected to an exhaustive study, the species being determined either from familiarity with the organism or from comparison with descriptions by various authors of organisms of the same genus and from the same host plants. In case of a well-known disease, it is believed that there is little chance for error in reporting its occurrence here if the typical signs are present on the same host and a similar fungus of the same genus is associated with the disturbance. It is expected that organisms associated with the more important diseases will receive critical study as opportunity permits.

DISEASES OF THE IRISH POTATO.

Many years ago the growing of Irish or white potatoes was a much more important industry in Hawaii than it is at the present time. Ships stopping here replenished their supplies with Kula potatoes, many of which were taken to California and around the Horn to the Atlantic seaboard. During one year 71,000 barrels are said to have been shipped. As a result of some condition or combination of circumstances, the potato industry has become relatively unimportant, although considerable quantities are still raised. It is believed that the diseases affecting the potato are the most potent factor in discouraging potato growing.

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[1] Hawaii Sta. Ext. Bul. 4, Emergency Ser. 11 (1917).

Until the division of pathology was established at this station, the diseases of the potato in Hawaii seem not to have been critically studied nor were the causes of the troubles determined. In a publication of this station,[1] without date, but probably issued in 1903, T. F. Sedgwick discusses certain preliminary experiments with the "quick blight" of potato. The disease as there described does not coincide with any one disease as observed by the writer but seems to have been a confusion of the two diseases, Fusarium wilt and late blight. The following is quoted from the description:

> The disease often wipes out whole fields of potatoes in a short time * * *. This disease of the potato has been confounded with the potato rot, but they are entirely different both in the cause and in their effect upon the plant. Until a better name is given we shall call it the "Quick Blight" of the potato * * *. Reports upon the disease from the Division of Pathology, Washington, D. C., indicate that it is caused by a Fusarium fungus * * *. The casual observer might not detect the disease until long after the destruction has begun, as there is little to indicate its presence. The vines usually make a good thrifty growth and seem to be healthy until shortly after blossoming, when without warning, the leaves and stem wither, turn black, and die to the ground as though bitten by frost.

Since the wilt disease caused by *Fusarium oxysporum* is prevalent in the section of Maui where Sedgwick carried on his varietal tests, it seems probable that this was the disease he had reference to, as possibly fields of Fusarium infected plants became attacked by late blight, such a combination of diseases being not uncommon in Kula. His preliminary experiments were not conclusive and apparently no further work was done.

The late-blight disease.—Serious trouble with the potato crop was probably first experienced when the late-blight disease (*Phytophthora infestans*) was introduced. Just when this happened has not been determined. The only mention found of this disease in Hawaii is in a report of May, 1913, of a pathological inspection trip on Hawaii by L. D. Larsen. In speaking of potato failures he says, "All indications point to the late blight (*Phytophthora infestans*) as the responsible factor." It is stated that no speciments were obtained for examination.

There is some ground for belief that *Phytophthora infestans* became serious in Maui about 1890. It is certain that this disease is now prevalent in the potato sections of Hawaii, Maui, and Oahu, but whether it occurs on the other islands of the group there has been no opportunity to determine. It is interesting to note in this connection that *Phytophthora infestans* has been reported as destructive in other tropical and subtropical countries, Butler[1] and Dastur[2] reporting it in India where, according to the latter, it is prevalent only in the hills, and Jehle[3] reporting it in Cuba where it is said to destroy annually a large part of the crop.

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[1] Hawaii Sta. Press Bul. 3.

In some sections of the islands, as in the vicinity of Glenwood, Hawaii, the weather is ideal for the development of Phytophthora every month in the year. In the Kula section of Maui and in the vicinity of Castner, Oahu, where there is considerably less rain, an outbreak can be expected at almost any time after a rainstorm or in a period when misty showers are of frequent occurrence. Although in general there may be said to be seasonal plantings of potatoes, about two main crops a year being common, the various periods of growth so overlap that growing vines and typically blighted plants can be found at any time somewhere in the islands.

Usually during the warmer part of the year, this disease is confined to the mountain slopes and cooler valleys, but a typical outbreak was observed at Mokuleia, Oahu, at sea level about April 13, which, however, made no progress during a week of dry hot weather. Some of the plants were sprayed April 20. Subsequent to spraying there was considerable rain on two different days. When examined about two weeks later, the unsprayed plants were badly diseased, the stems standing erect but the leaves rotting or drying up, while the sprayed plants were only slightly affected, presenting a striking contrast to the unsprayed rows. (See Pl. IV, fig. 1.)

A considerable number of demonstration sprayings of potatoes with 5:5:50 Bordeaux mixture have been made both on Oahu and on Maui, from which it appears that this disease can be largely prevented by proper spraying. It is being recommended that plants be sprayed first when 6 to 8 inches high and about every two weeks thereafter and after rains, or, in other words, often enough to keep the plants, and especially the new growth, continuously protected. The blight generally appears shortly after the time of blossoming.

Where it has been possible to properly conduct and supervise the spraying demonstration experiments, the results have been highly satisfactory. In the Kula section of Maui, where the demonstration of effective control methods would be of the most benefit, the distance from Honolulu and the difficulty of getting to the section have made it almost impossible to give the fields the attention needed. In consequence, heavy showers having in nearly every instance washed off the spray mixture a few days after it was applied, and the necessary cooperators not having been secured to make further applications at critical times, the results in this section have on the whole been less satisfactory than might otherwise have been the case. Because of this experience the work of demonstrating the use of Bordeaux mixture for the control of the late blight will be continued in Kula in cooperation with the extension division, under more auspicious circumstances than last year.

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[1] Butler, E. J. Potato diseases of India. Agr. Ledger, 1903, No. 4 (Crop Disease and Pest Ser. No. 7).

[2] Dastur, J. F. The potato blight in India. Mem. Dept. Agr. India, Bot. Ser., 7 (1915), No. 3.

[3] Jehle, R. A. Late blight of potato. Estac. Expt. Agron. Cuba Circ. 48 (1915), pp. 2–6.

The data from a spraying experiment conducted at Castner, Oahu, are summarized as an indication of what results may be expected from the intelligent use of Bordeaux mixture in controlling the late blight disease. The plat of potatoes under experiment consisted of 4 rows of 60 hills each. The seed was inspected and planted January 19 and the plants of the two inside rows were sprayed March 17, 19, and 27, altogether less than 10 gallons of 5:5:50 Bordeaux mixture being used. The tubers were dug April 10. (See Pl. IV, figs. 2 and 3.) The yields of the two rows of unsprayed plants were, respectively, 66 and 78 pounds, and for the sprayed plants, respectively, 110 and 116 pounds, a total weight of 226 pounds from 120 hills of sprayed plants and of 144 pounds from the same number of hills of unsprayed plants, the gain being 82 pounds, or 57 per cent. The blight was already well started when spraying was begun and blight-favoring weather continued for a relatively short period after the spray was applied. The experiment, therefore, was not conducted under the best conditions for maximum beneficial effect of the spray mixture. The spray material for the 120 hills cost about 20 cents, and the value of the increased yield at the market price of potatoes at the time was $4.10.

After the spraying of potatoes with Bordeaux mixture has become a general practice and the late blight is controlled or prevented to as great an extent as possible, attention will be directed to other diseases of this crop whose annual ravages are very serious. The full extent of the loss caused by these other diseases is unappreciated, the spectacular effects of late blight masking the injury due to the more insidious diseases.

Fusarium wilt disease.—The Fusarium wilt disease caused by the fungus *Fusarium oxysporum* was observed repeatedly in the fields about Waiakoa, Maui. The organism was isolated and identified from the discolored vascular bundles of the stems of wilted plants and from the vascular ring of young tubers from the same plants. The organism has also been repeatedly isolated and identified from California potatoes coming into the territory, both as seed and table stock. Before this disease can be controlled to any extent a source of disease-free seed will have to be found and much fundamental work done in establishing seed selection and crop rotation as general practices.

The characteristic signs of the wilt are not difficult to recognize. The plants grow well for some time—often until about the time of flowering—when they appear to suffer as from a shortage of water. The leaves droop and the margins may roll upward, the wilting effect being more noticeable at midday and partial recovery during the night being common. The leaves later become lighter green or slightly yellowed and gradually dry up, the plant dries prematurely, and the tubers do not reach full size.

The disease is brought about by a fungus, *Fusarium oxysporum*, growing in the vascular ducts of the stem and roots and mechanically interfering with the movement of water. If the underground stem of affected plants is split, the woody portion often shows a brown discoloration. Similarly, paring away the stem end of affected tubers often discloses a discoloration of the vascular ring. It is generally believed that the fungus continues to grow along the vascular bundles of the tuber after it is dug, and if such a tuber is used for seed the parasite grows directly from it into the new plant.

The measures, all of a sanitary nature, suggested for lessening the damage done by this disease on the mainland will quite probably be of value here. These include hill selection of seed, healthy plants being staked during the growing period, and the progeny of those plants remaining healthy being reserved for seed; and cutting off at planting time a thin slice at the stem end of tubers and discarding those lots of seed any considerable number of which show a brown discoloration at this point. Such selected seed should be planted on new soil or on soil which has not been in potatoes for at least three years. For the best interests of the potato industry each grower should maintain his own seed plat. All undesirable plants should be rigidly pulled or rogued out and the progeny of the best yielding, disease-free strains saved for seed.

Rosette disease.—The rosette disease caused by *Rhizoctonia solani* is more or less prevalent in all fields thus far seen. Where the main stems of potato plants are girdled by this fungus at or below the soil surface a rolling of the leaves often results. Such affected plants as observed here are usually only slightly dwarfed and present a somewhat straggling or spreading appearance. The leaves tend to roll upward and become light green or yellowish, and the forming tubers are collected on very short stolons in a bunch near the main stem. Small aerial tubers also occur.

The treatment for this disease consists in sanitary measures. It is probable that the fungus is carried by the seed in the form of the small sclerotia which adhere closely to the skin of the tuber and resemble a bit of dirt or soil. Seed selection, disinfection of seed in corrosive sublimate solution, and crop rotation are all important precautionary measures.

Scab diseases.—Common scab occurs in the islands, but no serious infection of tubers has yet been observed. The majority of the scab and skin blemishes observed are of the sort generally attributed to Rhizoctonia and to injuries brought about by the tuber moth (*Phthorimæa operculella*), wireworms, and cutworms.

Storage rots.—Potatoes grown in Hawaii are seldom stored for any length of time, as the fact that the entire crop of the islands is now such a small part of the total amount consumed favors immediate use of the home-grown product. Yet considerable loss, especially in seed stock, is brought about by the action of the late-blight fungus (*Phytophthora infestans*), the wilt fungus (*Fusarium oxysporum*), and the root-inhabiting fungus (*F. radicicola*), the two latter as wound parasites of the tubers.

As the porous soils in Kula dry out rapidly after a rain and the surface layers become heated in the sun, there is relatively slight damage from tubers rotting in the ground with the late blight fungus. Considerable loss in shipment to market is undoubtedly due to this sort of rot and to the secondary invasions which follow the late blight lesions.

A mite disease of potatoes.—A disease of potatoes, the cause of which is as yet not certainly established, is very prevalent and destructive on Oahu in hot weather. It was observed to begin early in May in the vicinity of Honolulu and about the middle of June at Castner. The disease is characterized by the withering and drying up of the new terminal growth and that in the leaf axils, the petioles also eventually becoming withered and dried. The stems remain erect with all the leaves dry and drooping. The trouble appears to be most prevalent in dry, hot weather, and most commonly attacks plants at the time of flowering. Examination of the slightly affected new growth, underneath the leaves of which there is usually a browning or bronzing as an early symptom, shows the presence of a quantity of mites and sculptured eggs. The mites are oval, of a slightly yellowish-brown color, the young having three pairs of legs, the adults four pairs. They are so small as to be almost invisible under a hand lens of a magnifying power of less than 20. Attacked new growth is also slightly more hairy or fuzzy than normal. The plants die in a short time (about 10 to 20 days) if seriously attacked. Whether the mites are entirely responsible for the trouble or only constantly associated with it remains to be determined.

This disease somewhat resembles the trouble described by Rolfs[1] on tomatoes in Florida, under the name Phytoptosis. Further studies of this disease and the identification of the mite by a specialist may suggest a better name for the trouble. The disease is very common in the vicinity of Honolulu and is the most destructive trouble after the weather becomes too warm and dry for late blight.

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[1] Rolfs, P. H. Florida Sta. Buls. 21 (1893), pp. 23, 24; 47 (1898), p. 143.

Rolfs suggests as a remedy for the tomato disease the use of dry sulphur or sulphur in Bordeaux mixture where the latter is being applied for this or other troubles. In the experience of this division, plants regularly sprayed with Bordeaux mixture alone were not badly attacked until about two weeks after the unsprayed plants in adjoining rows were infested. The Bordeaux apparently acts to some extent as a repellent.

BANANA DISEASES.

An Hawaiian disease of the banana.—A serious disease of the Bluefields variety of bananas (*Musa sapientum*) was observed on the plantation of T. Ikeda, near Hilo, Hawaii, in June, 1916, at which time all the plants in a projecting corner of the plantation comprising about one-fourth acre were badly diseased and many were dead. When the plantation was visited about six months later, the disease had involved the entire planting of bananas, about 3½ acres. The trouble resembles the Panama disease as described by Ashby[1] and Drost.[2] On plants about three-fourths grown the disease caused drooping and drying of the lower leaves and breaking of the leafstalks with a sharp angle near the pseudostem (see Pl. V, fig. 1), sometimes buckling and falling over of the plant at the ground level or at some point higher up on the pseudostem, yellowed and browned vascular traces more or less widespread throughout the plant (as evidenced in cross and longitudinal sections of several entire plants), and occasional cavities of soft, ill-smelling rot. The discoloration of the vascular elements is traceable from the stem of the bunch and from the base of the expanded portion of the leaves or crown through the pseudostem to the bulb, and in some cases to rotted brown areas of the larger roots. These rotted areas of the roots are observed to penetrate the root cortex to the central portion, and the discoloration extends along this central portion of the root for some distance beyond the surface lesion. The fruits, where these are present, are incompletely developed, withered, and useless, with the fingers blackened, those at the apex of the bunch being smaller and less developed than those nearer the plant.

A fungus of section Elegans of the genus Fusarium was isolated in an aseptic manner from the interior of three different plants and at heights from the ground varying from 1 to 7 feet. The diseased plants were cut and suitable pieces of the pseudostem taken to the

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[1] Ashby, S. F. Banana diseases in Jamaica. Bul. Dept. Agr. Jamaica, n. ser., 2 (1913), No. 6, pp. 95–149.

[2] Drost, A. W. De Surinaamsche Panamaziekte in de Gros Michel bacoven. Dept. Landb. Suriname Bul. 26 (1912). (Translated in article by S. F. Ashby.)

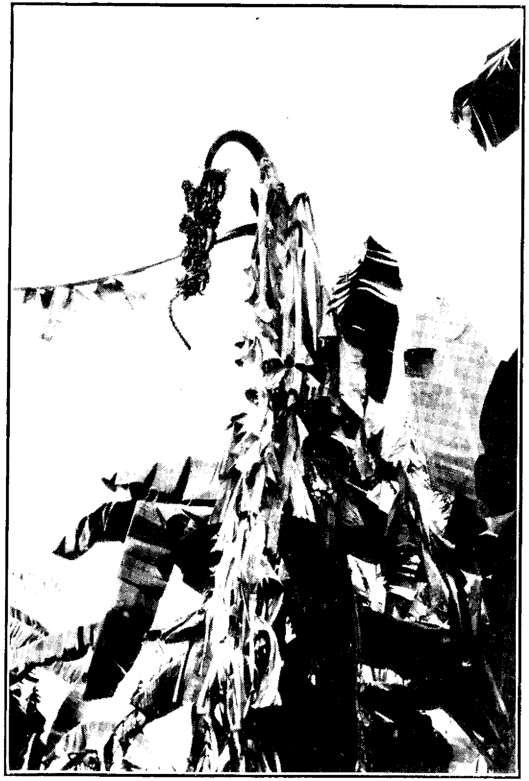

FIG. 1.—DISEASED BANANA PLANT, SHOWING DEAD AND DROOPING LEAVES.

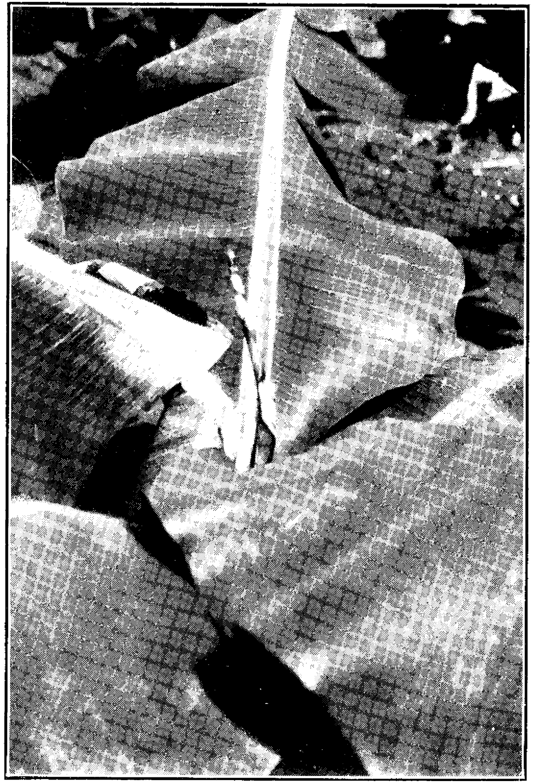

FIG. 2.—DISEASE OF CHINESE BANANA CHARACTERIZED BY ROTTING OF CENTRAL LEAVES.

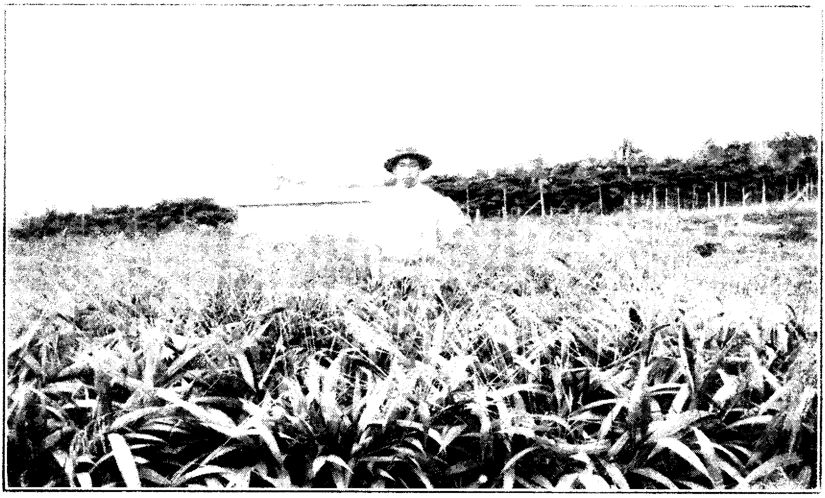

FIG. 1.—BAMBOO GRASS (PANICUM PALMIFOLIUM) AT GLENWOOD.

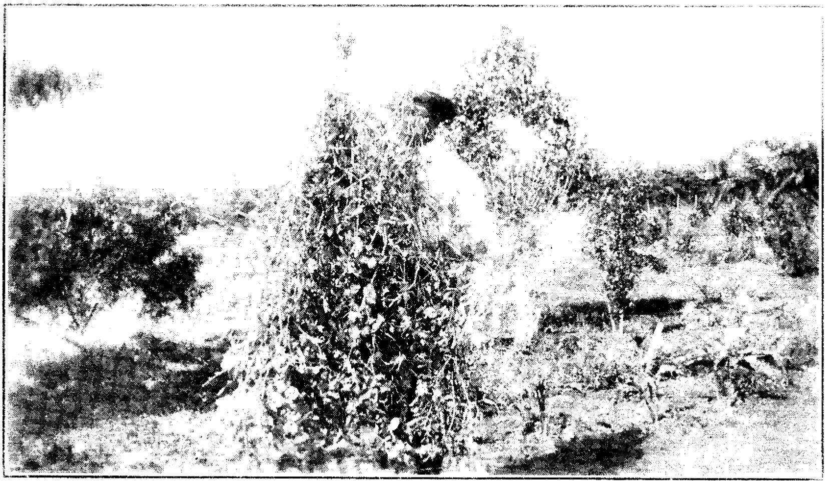

FIG. 2.—CANADA FIELD PEAS AT GLENWOOD.

laboratory, where the outer leaf sheaths were removed and dissected with sterile instruments, bits of discolored vascular strands being transferred to synthetic and beef agar plates and to tubes containing sterile plant stems, steamed rice, and potato cylinders. In a few cases bacterial contaminations were found, but the Fusarium generally developed in pure culture. The cultures were plated and reisolated.

The normal conidia of the Fusarium isolated by the writer are predominantly triseptate and, as above noted, are of the typical Elegans type. The cultural characters, that is, red coloration on steamed rice, blue sclerotia on potato cylinders, and salmon-colored pionnotes on sterile plant stems, also place the fungus in this section, which contains species with conidia of the same shape and comprises all of the vascular parasitic Fusaria. The Fusarium isolated here is considered identical with the one described as Fusarium A by Ashby. Sometime ago he sent the pathologist of this station, while the latter was still at Washington, D. C., subcultures of his Fusaria A and B for identification. His Fusarium A was reported as similar to *Fusarium vasinfectum* and Fusarium B was identified as *Fusarium radicicola.* Unfortunately, no cultures of Ashby's Fusarium A are available at the present time for exact comparison with the Hawaiian strain.

The disease as observed here differs from that described by Ashby in that the discolored vascular bundles are yellow and brown rather than red, in this respect resembling more the so-called Surinam Panama disease. The outer leaf sheaths were not observed to split to the ground as noted by Ashby and Drost.

G. L. Fawcett described a disease of the Chamaluco banana (*Musa paradisiaca*) in Porto Rico,[1] which also appears to be identical with the Hawaiian disease. A Fusarium said to be similar to Ashby's Fusarium A was found constantly associated with the trouble, but that it is the cause of the disease is not considered established.

Other diseases of bananas.—Among the other diseases of bananas there may be mentioned a disease of the Chinese variety (*Musá cavendishii*) characterized by a rotting of the young leaves while yet unrolled (see Pl. V, fig. 2), which is at times quite a serious trouble. If the tops of affected plants are removed soon enough with a cut well below the affected region, the plants frequently grow up in a healthy manner. The symptoms of the disease suggest the possibility that it is related to the so-called "moko" disease described by Rorer.[2]

Green fruits of the Chinese banana are attacked in wet weather by a disease causing the surface to become covered with minute grayish spots which later turn black. As the spots increase in size and number they coalesce and disfigure the fruits with a continuous black coating. In itself the disease is not serious, as the interior of the fruit is not harmed, but diseased fruits do not keep well and are not accepted for export. Considerable loss is in this way incurred. The black spots appear to be acervuli of a Glœosporium-like fungus.

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[1] Porto Rico Sta. Rpt. 1915, p. 36.

[2] Rorer, J. B. A bacterial disease of bananas and plantains. Phytopathology, 1 (1911), No. 2, pp. 45–49.

DISEASES OF MISCELLANEOUS PLANTS.

The diseases most frequently encountered on economic plants in Hawaii are caused by Glœosporium-like fungi, the majority perhaps being due to the same species. That this fungus will prove to be the imperfect stage of a Glomerella is to be expected after the fundamental work of Shear and Wood[1] with this confusing group. Thus far a Glœosporium-like fungus has been found associated in Hawaii with diseases of the following plants: Avocado, banana, cassava, coffee, fig, guava, litchi, mango, star apple, and vanilla.

Other diseases of importance which have been observed are as follows: On the bean, anthracnose (*Colletotrichum lindemuthianum*); cauliflower, a bacterial rot of the inflorescence; celery, late blight (*Septoria petroselini apii*); sweet potato, scurf (*Monilochætes infuscans*), soft rot (*Rhizopus* sp. and *Fusarium solani*), and leaf spot (*Septoria bataticola*); and tomato, leaf blight (*Septoria lycopersici*) and *Phytophthora infestans*.

REPORT OF THE GLENWOOD SUBSTATION.

By J. B. Thompson.

In the Glenwood section the past year has been one of the most trying periods in the history of diversified farming. The dairymen and poultry men are buying imported feeds and are paying prices 60 to 100 per cent higher than those paid one year ago, while the returns from their products have not kept pace with this increased cost of production. The cost of food, clothing, and all general necessities of life has advanced correspondingly, a condition adding to the already heavy burdens of the people and strongly emphasizing the importance of a system that will tend to augment home production, not only of stock feeds, but of table foods as well.

FORAGE CROPS.

The future of the Glenwood district seems at the present time to depend very largely upon the development of the dairy industry, while the development of that industry appears to be contingent upon the substitution of home-grown feeds for a portion or all of the expensive imported feeds that are now being used. The successful and profitable production of any of the ordinary grains is not especially promising in view of the heavy rains and the attendant difficulties in handling these crops, especially at the stage when the grain is approaching maturity. The production of a more adequate supply of nutritious green forage affords greater promise, and all prominence consistent with the resources at hand has been given to this line of the station work.

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[1] Shear, C. L., and Wood, Anna K. Studies of fungous parasites belonging to the genus Glomerella. U. S. Dept. Agr., Bur. Plant Indus. Bul. 252 (1913).

Paspalum dilatatum, or Paspalum grass, has continued to show good general results, but determinations of actual yields, or, more logically in the case of a pasture grass, trials that would indicate the grazing capacity of a given area, have not been found possible. An extension of the substation's plantings on an area of approximately 1⅕ acres was made in October, 1916, this tract being laid out in rows 30 inches apart and root divisions planted in these rows at intervals of 18 inches. The ground upon which this planting was made having been previously plowed and prepared, the combined operation of digging and dividing the roots and completing the planting required the entire time of one man for a period of nine days. With labor at the rate of $1.50 per day, the cost of planting alone amounted to $11.25 per acre, but when the permanent nature of this grass when once established is considered this expense does not appear to be excessively high. As the year's plantings are on soil of unusually low fertility the grass has made correspondingly slow growth, but at this time (eight months after planting) it shows a fair crop of pasture and a good crop of seed. The seed crop will be allowed to remain in the field in order that the germination of this seed where it falls at maturity may hasten improvement in the stand of this grass.

Panicum palmifolium, or *Chætochloa palmifolia*, the common bamboo grass of the islands, has been grown at the substation as a forage plant for the past two years and it has been found to possess considerable merit. This grass is sometimes grown in Hilo and its vicinity as an ornamental plant and it may also be observed in an uncultivated state throughout the island. Late in the season of 1915, F. G. Snow, of Glenwood, Hawaii, furnished the substation with two undivided root clumps of this grass, and from this stock sufficient material has been propagated for planting an area of approximately 3,000 square feet. This species having the habits of a bunch grass, divisions of the root clumps are grown with the greatest ease. It is also a most prolific seed bearer (Pl. VI, fig. 1). The seeds which fall to the ground at maturity germinate, giving young plants of rather slow growth during their earlier stage, but of increasingly rapid growth as the root system develops. The leaf sheaths and to a less extent the leaves themselves have stiff, bristly hairs that are unpleasant to laborers who cut and handle the crop, as they pierce the unprotected skin of the hands and wrists, leaving a disagreeable if not an extremely painful prickling sensation. This trouble may be avoided by wearing gloves while handling the green grass. At the substation this grass has been given reasonably clean cultivation on soil treated with fairly liberal applications of stable manure, under which conditions it promises to yield very satisfactory crops even during the cold season of the year when pasturage is scarce and most grasses make indifferent growth. Near the close of the year, a crop harvested from a small area yielded at the rate of 23.5 tons per acre. That the green grass is extremely palatable to stock and cattle is proved by the fact that this grass was cropped to the ground by animals gaining access to the experimental plats on February 17, while many other accessible crops, including red, white, crimson, peavine, and alsike clovers, growing in adjacent plats were left undisturbed.

Canada field peas have given full promise of success when planted during the cool season of the year on soil treated with heavy applications of stable manure. A garden plat seeded on November 20, 1916, made a remarkably vigorous growth, the vines running to a length of six feet or more (Pl. VI, fig. 2) and bearing a heavy crop of peas. On December 28, 1916, a planting was made on a well-manured field plat, the results from which compared favorably with those from the earlier field planting. Later plantings, in which commercial fertilizers were substituted for stable manure, were less successful, and the question remains to be answered as to whether these results were due to a warmer season of growth, or to a less favorable influence of commercial fertilizers, or to both. In an effort to study the fruiting habits of the pea under the climatic conditions obtaining at Glenwood, the tests have been continued beyond the soiling crop stage and no attempt has been made to obtain data relative to yields. Peas were borne in profusion, most of them developing well past the green-pea stage, but much loss due to excess moisture occurring as the crop approached maturity.

Improved Swedish oats, a variety for which resistance to rust is claimed, was planted on a garden plat on November 20, 1916, an application of stable manure estimated at 50 tons per acre being worked into the soil before planting. The crop made rank and vigorous growth, remained free from rust, and yielded at the rate of almost 24 tons of green feed per acre when the crop was cut on April 9. Plantings of the same variety were made on December 12 and 28 and on January 16, the first and last of these plantings being grown with sodium nitrate as the sole fertilizer, while the crop planted on December 28 was grown on soil given an application of stable manure at the rate of 56 tons per acre (see Pl. VII, fig. 1). As all these last crops were cut after a shorter period of growth than the first planting, none produced as heavy yields, but all gave excellent returns. A specially gratifying feature in the test of this variety is the fact that heavy crops were produced during the coolest season of the year when green feed is always scarce. The freedom of this crop from rust and attacks of aphids and its response to the application of commercial fertilizers, even on a soil extremely deficient in humus, are also important factors in its favor.

Spelt and spring rye drilled adjacent to and at the same time as the Improved Swedish oats planted on November 20 were badly infested with a species of aphis throughout the greater portion of the growing year, the spring rye being the more seriously damaged. The oats, notwithstanding its close proximity to the infested plats, remained free from these pests at all times. Of the same crops again planted in adjacent plats on December 28, spring rye and spelt were seriously attacked by plant lice, while the oats remained unharmed. On February 17, however, cattle invaded the experimental plats, feeding upon the bamboo grass and the plat of oats. Six days later young tender blades of oats, which had sprung to a height of 6 or 7 inches, were seen to be attacked by the aphids, indicating that new ratoon growth will perhaps always be susceptible to the ravages of this pest. The attack was not, however, made in great numbers nor was it a persistent one, the pests almost entirely disappearing after an infestation of about three weeks.

Spelt and spring rye were both planted during the year and, as has been pointed out in the preceding discussion, both were attacked by plant lice. These crops were cut after a period of growth covering 4½ months, spelt yielding at the rate of 15,687 pounds, and spring rye 17,430 pounds per acre. Neither of these crops promises to equal the Improved Swedish oats.

Thousand-headed kale and Dwarf Essex rape, drilled in rows on November 20 and transplanted to a permanent field location on January 5, both made vigorous growth during the cold season and yielded at the rate of 19.5 and 22 tons of green feed per acre, respectively. These plantings were made on thoroughly prepared soil fertilized with stable manure at the rate of 50 tons per acre before planting. Dwarf Essex rape, planted in April of the preceding fiscal year, was totally destroyed by cutworms, indicating that this crop and possibly the closely related kale are subject to serious damage from cutworms during the season when these pests are most prevalent.

Bur clover of six different species has been grown at the substation during the past fiscal year, their trial being suggested by the vigorous growth of a few volunteer plants of what was believed to be the ordinary California bur clover during the preceding fiscal year. Planting was made on well-manured and thoroughly prepared soil on November 20, 1916, seed of *Medicago scutellata*, *M. orbicularis*, *M. arabica*, *M. hispida*, *M. hispida sardoa*, *M. tuberculata*, all of which was obtained through C. A. Sahr, assistant agronomist of the station, being planted at that time. The growth of all species was extremely slow during the first ten weeks after planting, while all made rapid growth after that time. *Medicago scutellata* was the first to reach maturity and very plainly ranked lowest among all species in the production of forage. The planting was made on a very small scale, each species occupying 92 linear feet of drilled row, and no definite comparative yields could be obtained.

GROUND CHERRIES.

The extreme ease with which the native poha is grown throughout upper Olaa led to a test during the past fiscal year of the closely related and improved ground cherry from the United States. Seeds of two varieties, the improved ground cherry and Mammoth Purple-Fruited ground cherry, were obtained and sown in seed flats on February 2, 1917, the resulting seedlings being transplanted to the field on March 30. The improved ground cherry developed comparatively slowly and had a low, spreading habit of growth. The fruit is small, yellow, and sweet. As compared with the poha, the Improved ground cherry has, in this one test, produced a lighter yield and smaller fruit with no special improvement in flavor. The Mammoth Purple-Fruited ground cherry made a more rapid growth, the plants being comparatively large, erect, and very prolific. The crop from this planting has not yet fully matured, but fruits measuring more than 1¼ inches in diameter and very much larger than those of the ordinary poha have already been found. This variety is very promising and, due to the very large size of its fruit, is attracting much local interest. As the crop is yet immature, no comparative tests to determine the relative values of this variety and the poha as cooking fruits have been made.

BLIGHT RESISTANT POTATOES.

The only obstacle in the way of producing large yields of potatoes in the Glenwood section appears to be the presence of the potato blight. Stories of such bountiful potato crops that prices fell to 50 cents a bag in the days prior to the introduction of this disease are frequently related by the older residents of the district, and it is an unquestioned fact that the crop develops at present with unsurpassed vigor until the blight strikes it. Heavy and frequent rains favor the disease and also tend to render ineffective the employment of fungicidal sprays as a control measure. Having these conditions to contend with, work leading toward the discovery or development of a blight-resistant variety would appear to offer greatest promise of a satisfactory solution of the problem. During the past fiscal year five varieties of white potatoes advertised as possessing some degree of immunity to this disease were tested at Glenwood, all proving to have little or no resistant qualities. The variety Portuguese Red, having a deep red color and rather inferior quality, and known to be partially resistant to this disease, has been grown on the island of Hawaii for many years. During the past fiscal year material was obtained of two new varieties, these being secured from the originator, K. Yamato, of Honokaa, Hawaii, and grown in comparative tests with the Portuguese Red potato and five white varieties. These two varieties of what has been named the "Hamakua Hybrid" potato were exhibited at the Second Hawaii County Fair, held at Hilo September, 1916, and are here designated as Blue Ribbon and White Ribbon, from the prizes awarded them at that fair. The variety Blue Ribbon is of a light red color but quite distinct from the darker colored red Portuguese Red potato. White Ribbon is said to show some variation in color but is usually almost a pure white potato with eyes of a reddish-purple hue. Potatoes for the first comparative test were planted January 16, 1917. During the early stages of growth of this plat, several strong Kona winds so whipped and tore the plants that the presence of the blight could not be immediately detected, and comparisons could only be made of the final yields. All varieties were planted on the same date and plat, in rows of identical length, with equal distances between hills, with the same kind and quantity of fertilizer, and with the maintenance of uniformity in every controllable condition. The results of the tests, showing the relative yields of the different varieties in ounces per row, are shown in the following table:

Yields of potatoes in test of blight-resistant varieties.

Variety.	Number of rows.	Total yield.		Yield per row.
		Lbs.	*Oz.*	*Ounces.*
State of Maine	3	12	9	67
Green Mountain	3	13	4	71
Vermont Gold Coin	4	20	12	83
Eureka Extra Early	4	22	0	88
Great Divide	2	11	4	90
Portuguese Red	3	21	8	115
Blue Ribbon (Hamakua Hybrid)	3	25	7	136
White Ribbon (Hamakua Hybrid)	3	25	0	171

Another trial was begun on March 16, 1917, of single rows each of the varieties Vermont Gold Coin, White Ribbon, Eureka Extra Early, Blue Ribbon, State of Maine, and Portuguese Red, planted under identical conditions. These rows were arranged adjacently with the varieties in the order named above so as to alternate rows of the nonresistant potatoes with rows of the resistant varieties and thus to make the results more impressive during the test. Blight was first observed on all white varieties on April 21, but it did not appear on the White Ribbon, Blue Ribbon, or Portuguese Red until May 8. The progress of the attack was much more rapid in the case of the white potatoes than in that of the resistant varieties. Photographic views (Pl. VII, fig. 2) taken on May 26 show all plants of the ordinary white varieties completely dead, while those of the three resistant varieties are still making vigorous growth. As the experiment was still in progress at the close of the fiscal year, comparative yields could not be reported. The study of these promising varieties will be continued during the coming year.

REPORT OF THE AGRONOMY DIVISION.

By C. A. Sahr.

In addition to the regular work of this division a project was begun on the edible canna (*Canna edulis*), the object in view being the production throughout the islands of this most important food plant. Because of the shortage of labor, work on the fiber projects inaugurated in 1916 was dropped for an indefinite period. Active work on some of the other projects was also dropped temporarily in order that this division might concentrate its efforts on increasing local food production.

AQUATIC CROPS.

The work with rice and taro was continued at Waiau, Oahu. In relation to the aeration of soil tests with rice it is of interest to note that the comparative differences in yields of the aerated and nonaerated plats have grown considerably less. Neither of the plats received either manure or fertilizer for some time previous to the beginning of this test, in which, in 1916, the increase favoring nonaeration was 18.7 per cent for the spring crop, 4.9 per cent for the fall crop, and 3.1 per cent for the 1917 spring crop. As in previous tests at Waiau, Oahu, the variety of rice grown is the Bezembo.

POTATOES.

Owing to the saturated condition of the soil this year at the central station the planting of Irish potatoes was postponed until the second week in April, a much later season than usual. Inasmuch as the object of the planting is to obtain material for pathological investigations, supervision of the planting, cultivation, and spraying with fungicides of the stands obtained is almost entirely under the direction of the pathologist.

In a duplicate planting of Burbank and Early Rose potatoes at the Tantalus substation, an average yield per hill of 0.47 pound was obtained with both varieties. These very low yields are attributed to attack by mites, in addition to the effect of dry weather.

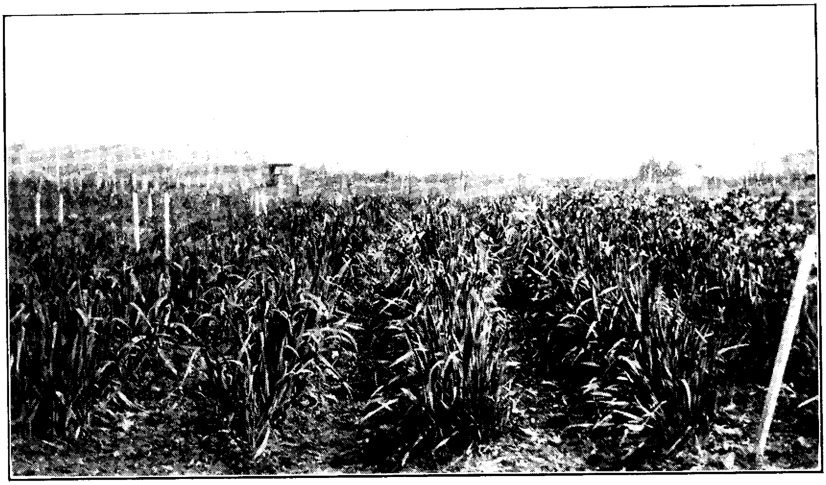

FIG. 1.—IMPROVED SWEDISH OATS AT GLENWOOD.

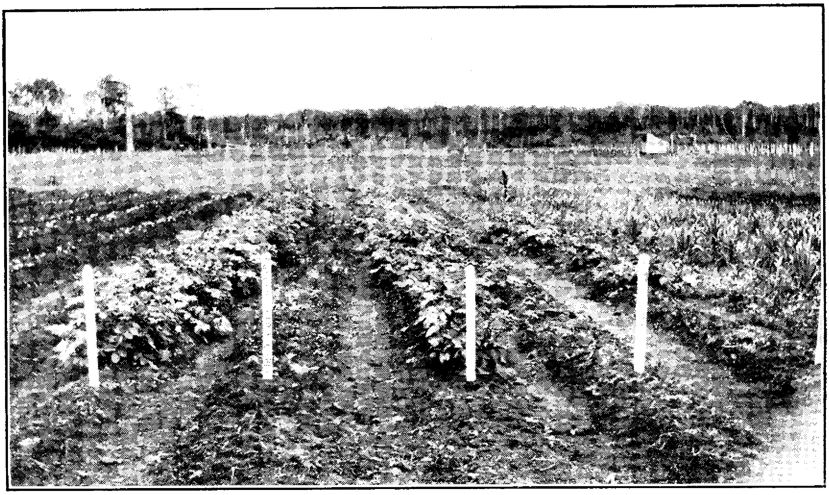

FIG. 2.—BLIGHT RESISTANT POTATOES. HAMAKUA HYBRIDS UNAFFECTED, OTHER VARIETIES BLIGHTED.

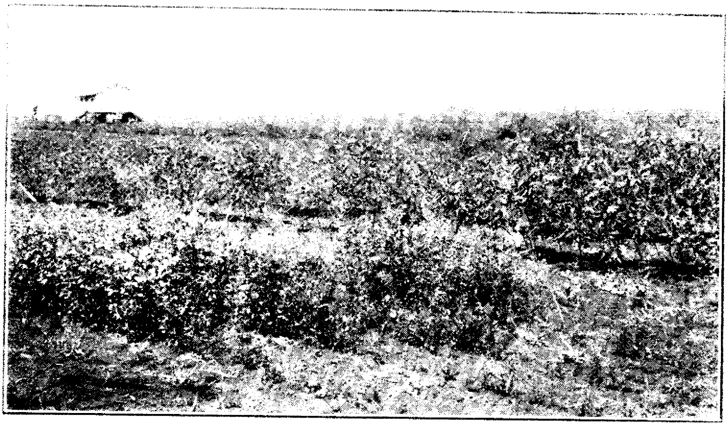

Fig. 1.—Peruvian Alfalfa, Showing Stimulated Growth Where Brush was Burned.

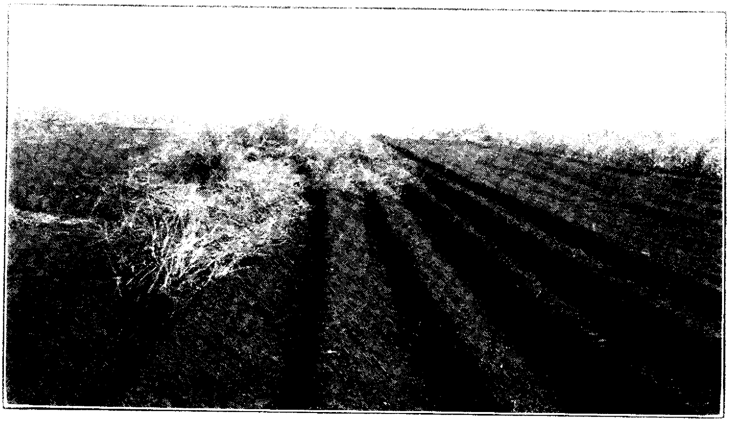

Fig. 2.—Preparation for Heat Treatment in Soil Experiment.

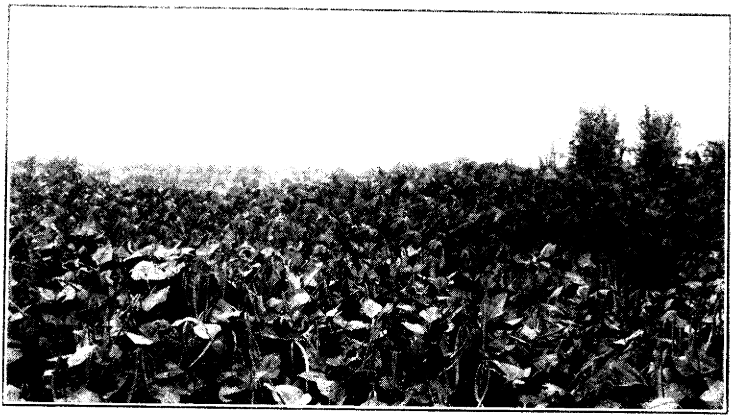

Fig. 3.—Effect of Heat Treatment and Stable Manure. Cowpeas in Foreground, Cassava in Background.

In order to obtain cuttings to supply the growing demand for propagating material of good types of the sweet potato, about five-eighths acre was planted to three varieties of this root crop, in the selection of which the determining factors were medium early maturity and heavy foliage, together with reported resistance to attack by the sweet potato leaf miner.

LEGUMES.

A new variety of pigeon pea (*Cajanus indicus*) from India, seed of which was received from the Haiku substation in 1915, has been tried out with favorable results by the division. This variety is not nearly so tall and erect as are the varieties of Porto Rican introduction, but it is much more bushy in habit of growth and its leaves are from one-fourth to one-third larger than those of the West Indian type. The pods are small, averaging 2 inches for the entire length, three to five seeded, and noticeably notated (marbled), with the peas about two-thirds the size of the Porto Rican variety Chiquita.

From records of various tests of alfalfa for a period of 32 months, individual yields based upon 9 cuttings per annum are as follows: Utah Common, 30 tons green forage per acre; Kansas Common, 28.4 tons; Peruvian, 21.7 tons; and Turkestan, 14.7 tons. From the same number of cuttings per annum for a period of 28 months, the individual yields from Grimm, dryland, and common alfalfa are, respectively, 26.6, 26.4, and 9.3 tons.

Ordinarily alfalfa can be cut once a month throughout the year. However, on the sloping fields of this station, to omit cutting during excessively wet periods has been found to lessen erosion.

Tests with tepary beans for seed yields have given varying results. A fall sowing made in field B of the station grounds produced a growth of 9 inches, the plants dying before blooming, probably because of saturated soil conditions. A second sowing in Magazine field, drilled 1½ feet apart, failed to make sufficient growth to fill the space between the drills but yielded at the rate of 10 bushels of shelled beans to the acre. In the third test, planting was postponed until drier conditions prevailed. The beans, drilled in furrows 2 feet apart at the rate of 15 pounds per acre, reached maturity in 76 days from the time of sowing and yielded at the rate of 33.4 bushels of 60 pounds each per acre.

GRASSES.

Roots of *Polytrias præmorsa* (S. P. I. No. 32111) and blue couch grass (*Digitaria didactyla*) were received October 26, 1916, and were set out in the forage crop garden the same day. The resulting plants of *Polytrias praemorsa* came into bloom and set seed early in February, 1917, the blooming continuing from then on. The two original roots of this grass have grown into a single sod now covering about 4 square feet. The growth assumed by the blue couch grass, while considerably more spreading, has not yet made any sod nor come into bloom.

With Napier grass (*Pennisetum purpureum*) the blooming periods seem to be limited to the months of April and November. A trial cutting of this grass made late in April, after its third blooming period from the time of planting, indicated a yield of 46 tons green forage per acre. It is planned to cut this grass, which ratoons freely, after each blooming period. Although protected from birds by a large cage, the heads do not seem to produce seed of germinative ability.

Of the demonstration plats in field X planted to Wilder, fuzzy top, Australian blue, and Natal redtop grass, the last two are producing the largest yields. These last two grasses may be cut for hay or forage at intervals of 70 days, but the Wilder and fuzzy top, though furnishing considerable herbage well adapted for pasture, do not head out well excepting in March and October.

SORGHUMS.

No new varieties of sorghums of either grain or forage types were tried during the fiscal year. Of the stand of seven varieties maintained for records of longevity and yields, the Sugar Drip sowed in April, 1915, one year previous to the sowing of the grain varieties in this test, still maintains the lead in yields of both grain and forage. Owing to the ravages of birds and the shortage of labor for the protection of the maturing crops of seed, it has been possible to mature only a single grain crop annually.

NUT-GRASS CONTROL.

The work in nut-grass control has shown decided results from spraying with arsenate of soda. During the first year of this work the nut grass required spraying at average intervals of 40 days, or whenever it was in full bloom, and during the second year at average intervals of 65 days. In the past year the last spray was applied in October, and while new shoots have sprung up since this application, no blooms have yet appeared during this period of nine months. The spray formula used in nut-grass control is 1 pound white arsenic, one-half pound caustic soda, and 1 gallon water. The mixture should be boiled until clear and diluted with water to 20 gallons.

CORN.

Owing to the severe attacks by the leaf hopper (*Peregrinus maidis*) the variety and fertilizer tests with corn have failed. A planting of sweet corn made in November, 1916, was found to be infested with the leaf hopper during the latter part of December. Through the cooperation of the Territorial Board of Agriculture and Forestry, a large number of corn leaf hopper parasites (*Ootetrastichus* sp.) were obtained and released at various periods during the life of the corn stand. In this manner the corn hopper was controlled sufficiently to bring the stand of sweet corn to maturity, the yield being at the rate of 43 bushels of ear corn per acre. However, owing to the start obtained by the leaf hopper in the first planting of sweet corn, a second test with Reid's Yellow Dent corn failed entirely.

RAPE.

Seed of Dwarf Essex rape distributed to farmers for poultry pasturage have brought reports of a very satisfactory nature to the division.

EDIBLE CANNA.

A planting of edible canna (*Canna edulis*) was made December 8, 1915, from a small quantity of tubers received from Judge J. A. Matthewman, Kailua, Hawaii. Of the resulting eight plants, one was pulled June 6, 1916, yielding 8.5 pounds roots and 8.25 pounds foliage, the remaining seven being harvested January 26, 1917, with a yield of 59 pounds mature tubers, 52.5 pounds immature tubers or suckers, and 52 pounds forage (leaves and stems), a rate of 23 tons edible tubers, 20.5 tons immature tubers, and 20.25 tons forage per acre. As the exact time that the edible canna was first introduced into this Territory is not known (though it is believed to have been about 1898), information regarding its introduction will be gladly received. In various districts of the Territory, it has been grown largely during the last few years by the native Hawaiians, forming a considerable portion of their diet. The plant sends out new shoots at various periods, the corms of which form the propagatory portions of the plant. Under Honolulu conditions, the stems attain a height of 5 to 8 feet and blossom in 4 to 6 months. The light green leaves and scarlet blooms render the plant quite valuable as an ornamental.

CASSAVA.

Two varieties of cassava, a white sweet sort from Trinidad and the red bitter kind common in the islands, were planted in the summer of 1915. Both stands were harvested in March, 1917, the white variety yielding at the rate of 31 tons, the red 16¼ tons fresh roots per acre.

A second planting of the same varieties was made at Magazine field in February, 1916, which should have been harvested in June, 1917, but owing to the demand for cuttings during the present food emergency, harvesting the roots has been deferred in order to save time in the production of cutting material.

SEED DISTRIBUTION.

During the early part of the fiscal year the demand was chiefly for seeds and cuttings of pasturing and soiling crops. Seed of several tame grasses were imported from the mainland in lots of 50 pounds each for distribution among the farmers and graziers at the higher elevations, but distribution was deferred in order to meet a possible shortage of seed in the near future. Cassava cuttings, of which 37,000 were distributed between April 1 and June 30, 1917, and edible canna tubers, of which 1,600 pounds was sent out for home-garden planting, were the chief food plant distributions during the year.

FORAGE-CROP PROBLEMS AT CASTNER, OAHU.

Preliminary work upon the forage-crop problem was begun in July, 1916, on the 13-acre tract set aside for experimental planting on the military reservation at Castner, Oahu. A rain gauge was installed June 30, 1916, and a careful precipitation record has been kept.

Analyses made by the station chemist for the manganese content of six samples of surface soil (first foot) and subsoil (second foot) showed from 1.24 to 6.02 per cent manganese dioxid in the surface soil and from 0.7 to 3.67 per cent in the subsoil.

From preliminary plantings of Sudan grass and common alfalfa made by Capt. John S. Fair, of the Quartermaster Corps of the Army, in February, 1916, it was observed that in four months these crops had only 40 per cent stands in normal soil, even though the rainfall had been unusually good. The entire tract was divided into 9 sections, each 115 feet wide. As a dividing line between each section and also to serve as a windbreak, 2 rows of pigeon peas 5 feet apart were sown at distances of 110 feet, bringing the dividing line between the sections midway between the pigeon-pea rows.

The planting of forage crops began July 21, 1916, in section VII, which was sown entirely to grain and sweet sorghums. Section VI was planted to an African nonsaccharin sorghum (Adyiba) and Sudan and Tunis grass. Section V was planted August 4, 1916, to Japanese, pearl, and Chinese millets, teosinte, and Japanese cane.

In every case rain followed these planting days in sufficient quantity to bring up the seeds. It was observed, however, in the course of a week that the stands had become so depleted by birds (plover and skylarks), which fed upon the young green shoots, that it was necessary to replant all of the sections, excepting the Japanese cane, on August 15, 1916. Good stands of all but teosinte were obtained and maintained, but due to the effect of the manganese soil all crops, with the exception of the pigeon peas and Japanese cane, succumbed entirely, following a period of about 70 days' stunted growth.

Planting operations were resumed in section VII late in October, following very good rains. Peruvian alfalfa was sown in two plats of five drills each, the drills being spaced 1½ feet in the first plat and 2 feet in the second. Pearl millet was sown in two plats of five drills each at distances between drills of 2 feet and 3 feet, respectively. Single plats of five rows each, spaced 2 feet apart, were sown to Japanese and Chinese millet, the rest of section VII being sown to sunn hemp. Very good stands were obtained in this planting. While moist conditions prevailed until the end of May, 1917, the various stands, although keeping alive, made no better growth than the summer planting had made, except on small areas of 2 or 4 square yards in extent scattered throughout the section. Investigation showed that piles of brush had been burned on these small areas, as evidenced by bits of charred stems through the soil. Only the sunn hemp made perceptible growth throughout the wet season. The millet died out when the dry season set in late in May. During the last week of May the alfalfa plats came into bloom at a height of 13 inches, and were cut June 2. The growth put forth by the alfalfa stands since this cutting (30 days), aided by a rainfall of 1.15 inches for that period, indicates that the next cutting may yield possibly 40 per cent of normal.

Due to the observed stimulating effect upon the growth of plants occupying small areas where brush heaps had been burned (see Pl. VIII, fig. 1), it was thought promising to test the effect of brush burning on a large scale in conjunction with a heavy application of barnyard manure. A strip of land in section VIII, 560 feet long and 50 feet wide, was lined off after plowing into four divisions each 12 feet wide and each treated for its entire length as follows: Division A, check, no treatment; division B, soil ditched 1 foot deep and piled with brush for burning (see Pl. VIII, fig. 2); division C, soil leveled, piled with brush for burning; division D, soil ditched 1 foot deep, given stable manure at the rate of 33 tons per acre and rolled level. Divisions B and C were burned off following the completion of the brush piling. The ashes on the surface of division C were swept into the furrow or dividing line between divisions C and

B, the object being to determine whether the results were due to heat or to the manurial effect of the ashes or to both. Divisions B, C, and D were then thoroughly cultivated with a five-shovel horse hoe and lined off for planting in furrows 18 inches apart. Each division was then marked out in plats 12 feet in length. The crops, of which there are 45, were planted in plats side by side, so as to be represented in each division. With the exception of the root crops, sorghum, cowpeas, and pigeon peas, which were planted in furrows 3 feet apart, all the plats were sown in 18-inch rows. All planting was done during the second and third week of March, 1917.

The resulting growth of the crops (see Pl. VIII, fig. 3) in response to the different treatments, made on a basis of 100 per cent for normal growth under normal soil and moisture conditions, for all the full stands are given in the accompanying table:

Effect of heat treatment and stable manure on manganese soil.

[Based on 100 per cent for normal growth.]

Crop.	Division A, no treatment.	Division B, ditched soil heated.	Division C, level soil burned over.	Division D, stable manure, 33 tons per acre.
Grasses:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Rhodes	15	80	20	100
Tall meadow oat	5	10	10	30
Bromus inermis	5	10	10	15
Teff	10	50	45	100
Bermuda	5	35	60	100
Giant Bermuda	10	30	20	60
Mitchell	5	15	5	100
Sudan	10	40	60	100
Australian water	0	5	5	30
Fuzzy top	5	10	10	20
Wilder	5	10	10	20
Tunis	5	25	15	100
Oats:				
Sixty-Day	20	60	55	50
Fulghum	25	70	40	80
Red Rustproof	20	40	35	60
Swedish Select	10	50	30	70
Victory	10	65	60	70
Swedish Victory	10	65	60	70
Swedish Crown	20	55	65	70
Wheat:				
Galgalos	30	55	55	60
Palouse Bluestem	10	45	55	80
Little Club	10	45	55	70
Japanese millet	30	30	30	40
Edible canna	20	30	40	50
Sorghum:				
Adyiba	5	15	20	90
Sugar Drip	30	20	40	100
Cassava:				
Bitter	40	55	60	100
Sweet	50	60	60	100
Legumes:				
Peruvian alfalfa	10	55	50	70
White sweet clover	5	40	30	60
Iron cowpeas	20	75	90	100
Kulthi	10	20	20	30
Muth bean	65	75	70	90
Tepary bean	60	75	85	95
Pigeon pea	60	85	90	100

Other important work on the production of forage crops on manganese soils includes a study of the effect of spraying the various crops with iron compounds. Portions of the stands of jack beans, pigeon peas, velvet beans, alfalfa, millet, Japanese cane, and grasses were sprayed every two weeks during April and May with a 2½ per cent solution of copperas, because of the burning effect of which strength the spray for succeeding applications was diluted to 1¼ per cent. Effects of the spray were slightly noticeable on the alfalfa previous to the cutting made June 2, but not on later growth. With the Japanese cane, however, the effects were clearly discernible.

REPORT OF THE TERRITORIAL MARKETING DIVISION.

By A. T. Longley.

The volume of business transacted by the division during the year was greater than for any previous year in its history. Sixty kinds of island products were marketed for 474 different consignors. The individual consignments, numbering 2,538, which included nearly every island agricultural product from green vegetables and preserved fruit to dressed meat and live stock, and ranged in value from a few cents to more than a thousand dollars, were sold for a total of $121,512.90. In addition to the consignment sales, seeds, crates, and merchandise valued at $18,006.15 were sold to producers and others. The number of individual consignors from the different islands were as follows: Oahu, 321; Hawaii, 73; Maui, 45; Molokai, 24; Kauai, 11. While Oahu led in the number of consignors and consignments, Maui's shipments, which were made up largely of beef, hogs, corn, beans, and potatoes, were of much greater value.

The retail meat and vegetable branches were established to furnish an outlet for the consigned produce which could not be sold to advantage to the local retail stores. It was the intention to run these on a basis which would be just self-supporting, and although they did not quite pay for the cost of operation, they served a most useful purpose in that they greatly increased the returns of the consignment branch. Until these retail departments were established the division experienced great difficulty at times in disposing of consigned produce to local dealers and often large quantities of perishable fruits and vegetables were lost. With the establishment of the retail branches it became possible to dispose of all such produce directly to the consumer in case the local stores were not in the market at that time. One reason for the difficulty experienced in selling locally grown consignments of vegetables to the retail stores is that most of them have regular standing orders for such produce to be shipped each week from the coast, the island-grown supply having been irregular in coming into the market and frequently not put up in the packages desired by the trade.

The recent session of the legislature increased the appropriation for operating expenses for the ensuing biennium from $24,000 to $30,000. In addition to this, the sum of $5,000 was appropriated for extension work among the producers, advising them as to what and when to plant and how best to prepare and grade for shipment to market. The producer often does not understand what the consumer demands, and without definite instruction along these lines he is not in a position to compete with the mainland concerns which have long since realized the economic necessity of standardizing their products. A special revolving fund of $2,500 was provided to permit the purchase of vegetable and other food-crop seed for sale at cost plus actual selling expenses. The revolving fund of $7,500 provided by the legislature in 1915 was increased to $15,000 and made more readily available for paying consignors. Of the original $7,500 there is on deposit with the Territorial treasurer the sum of $2,638.19, while $2,894.69 is represented by an inventory of pineapple crates on hand and $1,967.12 by accounts receivable.

An act was passed at the last session of the legislature defining the powers and duties of the division and placing it under the supervision of the Board of Commissioners of Agriculture and Forestry of the Territory, beginning July 1, 1917.

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HAWAII AGRICULTURAL EXPERIMENT STATION,
J. M. WESTGATE, Agronomist in Charge,
Honolulu, Hawaii.

Under the supervision of the STATES RELATIONS SERVICE,
Office of Experiment Stations, U. S. Department of Agriculture.

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION.

1918.

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Issued April 10, 1919

WASHINGTON
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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the States Relations Service, United States Department of Agriculture.]

E. W. ALLEN, *Chief of Office of Experiment Stations.*

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LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, July 15, 1918.

SIR: I have the honor to transmit herewith and to recommend for publication a report of the Hawaii Agricultural Experiment Station, 1918.

Respectfully,

J. M. WESTGATE,
Agronomist in Charge.

DR. A. C. TRUE,
Director States Relations Service,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
D. F. HOUSTON,
Secretary of Agriculture.

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[1] Resigned June 30, 1918.

[2] In military service.

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REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1918.

SUMMARY OF INVESTIGATIONS.

By J. M. WESTGATE, *Agronomist in Charge.*

INTRODUCTION.

The continued world food shortage of the past year revealed more clearly than ever the great dependence of the population of Hawaii on imported food products. Any interruption of shipping under such conditions immediately causes a severe disorganization in the distribution of food products. This has served to emphasize more and more the need of a greater production of locally grown foods. What the islands need most in an economic way is the development of diversified industries to provide a surplus of edible manufactured products which can serve as articles of export during normal times and which in times of dire necessity can be readily utilized to feed the local population. Sugar can be used only to a very limited extent to replace the starches in the human dietary, but, were such an industry as the manufacture of tapioca from cassava successfully launched, the cassava starch and flour could readily be utilized as food whenever necessary.

EMERGENCY WAR GARDENS.

Throughout the year, especial attention has been given to the development of the war-garden idea among those who became interested in doing something practical along food production lines. The station has continued to allot small plats of otherwise waste land to its laborers for the purpose of enabling them to maintain demonstration war gardens to serve not only as sources of foodstuffs but also as object lessons to the public, several of these gardens being located immediately in front of the station buildings. The gardens have also provided opportunity for successful demonstrations of the efficiency of spraying to overcome various insect and plant disease pests which are always troublesome under local conditions. The station has continued to supply cuttings, roots, tubers, seeds, and seedlings of such food plants as have not been regularly carried on the local market. It has also been freely consulted in regard to the best means of overcoming the various handicaps to production encountered by local home gardeners.

COOPERATION WITH MILITARY POSTS.

Under the broad policy of the commanding officers, the military posts have continued to contribute materially to the available food supply of the islands through their system of company gardens. At a number of the posts as much as an acre has been assigned to a company and special details made for each company garden. These details ordinarily consist of individuals who having had special experience in market gardening, are naturally enthusiastic in the work, and they have cooperated intelligently with the station in many ways. It is a pleasure to record that at the recent Territorial fair one of the companies won the blue ribbon for the best exhibit of white potatoes.

COOPERATION WITH PRIVATE GROWERS.

Considerable attention has been given during the year to the development and furthering of cooperative relations between the station and numerous private growers and concerns throughout the Territory. In these cooperative arrangements the station provides the plan for some experiment or demonstration which promises to give valuable information to the section in question. The necessary seed is also usually furnished by the station, while the cooperating individual furnishes the land and labor. The chief beneficial result of this work is that the cooperating grower provides himself with a first-hand demonstration of the relative merits of several of the most promising agricultural practices in connection with the crop or crops in question under his immediate local conditions. There is, therefore, no question as to the application of the findings of such cooperative experimental work. In addition to this, the station benefits in that it obtains valuable additional data concerning the responses of the various crops to the individual treatment given. A further educational benefit is derived, not only by the cooperative growers but also by the neighboring farmers, from the first-hand demonstration furnished by such work as to the desirability of each grower being his own experimenter, at least on a small or simple scale. The growers soon come to realize the advisability of always leaving a check plat to serve as a basis of comparison when trying out any special treatment on field scale.

THE TERRITORIAL FAIR.

The Territorial fair, held primarily for the purpose of stimulating food production and food conservation, was one of the most successful enterprises ever launched in the islands. The result of the food production propaganda of the past few years was demonstrated by the wide range of food crops placed on exhibit by growers representing nearly a dozen different nationalities. The cooperation of the military authorities in the way of equipment, organization, and program events contributed very materially to the success of the undertaking. All the agricultural institutions of the islands presented practical exhibits of their work, demonstrating either increased production or conservation of local foods.

One feature of no little interest was the daily exhibition of foods of the various nationalities, especially of the Japanese, Chinese, and Hawaiians, who demonstrated such of their foods as they considered best adapted for use as substitutes for wheat and other imported articles of diet.

Other very gratifying exhibits were those entered by a number of sugar plantations, showing the progress made in putting these plantations on a self-supporting basis as regards food for their laborers and feed for their work animals. One of the largest plantations presented evidence showing that it has been able to produce practically all the concentrate and roughage feed required by the thousand or more work animals in use on its properties. Another plantation company showed an interesting exhibit demonstrating the possibility of producing a form of alcohol from waste cane molasses for use as a substitute for gasoline. The same company has also developed a corn-meal grinding plant, a small model of which was in operation at the fair.

The general nature of the station's exhibits is indicated in Plates I, II, VI, and VII.

HORTICULTURAL INVESTIGATIONS.

The work of the horticultural division during the past year was principally concerned with the production of fruits and vegetables and especially the increased utilization of the banana, papaya, and tomato as food crops, particularly promising varieties of these being distributed as rapidly as propagating material could be made available. The division continued to give every possible support to the school and home garden propaganda work which has been very actively under way throughout the year.

One of the most promising phases of the work was a comprehensive test of numerous varieties of beans to determine the varieties best adapted for use not only as fresh string beans but also as commercial canning material for the pineapple companies, which necessarily are not in active operation during the considerable portion of the year when pineapples are out of season. It has been felt that the production of beans for canning on a large scale would serve to keep the canning plants in operation and also provide work for the labor force of the pineapple companies throughout the year.

An interesting experiment was continued looking to the development of a tomato resistant to the melon fly. Various hybrids have been made between the tomato of normal size, which is much subject to the attacks of the melon fly, and several strains of small tomatoes, including the wild tomato, which are resistant to the ravages of this fly. Several of the resulting hybrids have proved of good quality and sufficiently resistant to the fly to make a very welcome addition to the food supply of the islands.

CHEMICAL INVESTIGATIONS.

The drying of Hawaiian fruits and vegetables was considered of such practical importance as to receive most of the attention of the chemical division during the past year. It is not ordinarily practicable to produce a perfectly regular supply of some perishable food crops throughout the year. The customary gluts in the market at periods of overproduction have always served as a great deterrent to many growers who would otherwise produce food crops on a much more extensive scale. The consuming public in the islands, as regards any particular food crop, is somewhat limited, and a very ordinary overproduction will rapidly glut the market. It has been felt that if the overproduction at any season could be taken care of by means of commercial driers, the market would be stabilized and the growing of such produce would be put on a much more substantial foundation. It is also felt that there may be a considerable future in the production of vegetables for drying for export on a commercial scale. The economy in shipping space, packing materials, etc., favors the drying of vegetables which are to be consumed at any great distance from the point of production. This project has been furthered through the effective cooperation of Frank C. Atherton, of Honolulu.

During the year a summary of all available analyses of Hawaiian feeding stuffs was brought together and published in convenient form for ready reference.[1]

During November and December, 1917, the chemist made an inspection trip through Florida, Cuba, the Isle of Pines, and Porto Rico, where much information regarding the production of pineapples was obtained. This trip was made possible through the cooperation of the Hawaiian Pineapple Packers' Association.

The fertilizer experiments of the division have been continued, principally with rice, bananas, and pineapples. The field work has been chiefly in cooperation with private interests, while preliminary

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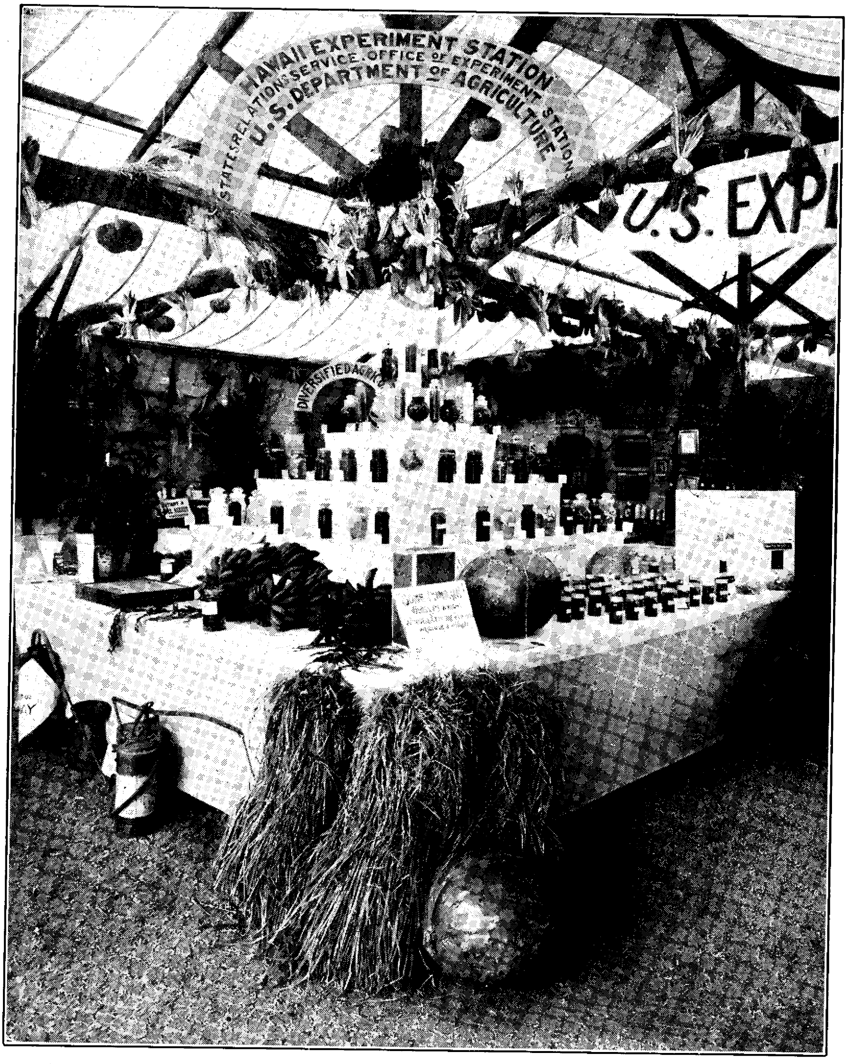
[1] Hawaii Sta. Press Bul. 53 (1918).


HAWAII EXPERIMENT STATION
STATES RELATIONS SERVICE. OFFICE OF EXPERIMENT STATIONS
U. S. DEPARTMENT OF AGRICULTURE
U.S. EXP
DIVERSIFIED AGRIC

GENERAL VIEW OF EXPERIMENT STATION EXHIBIT AT TERRITORIAL FAIR.

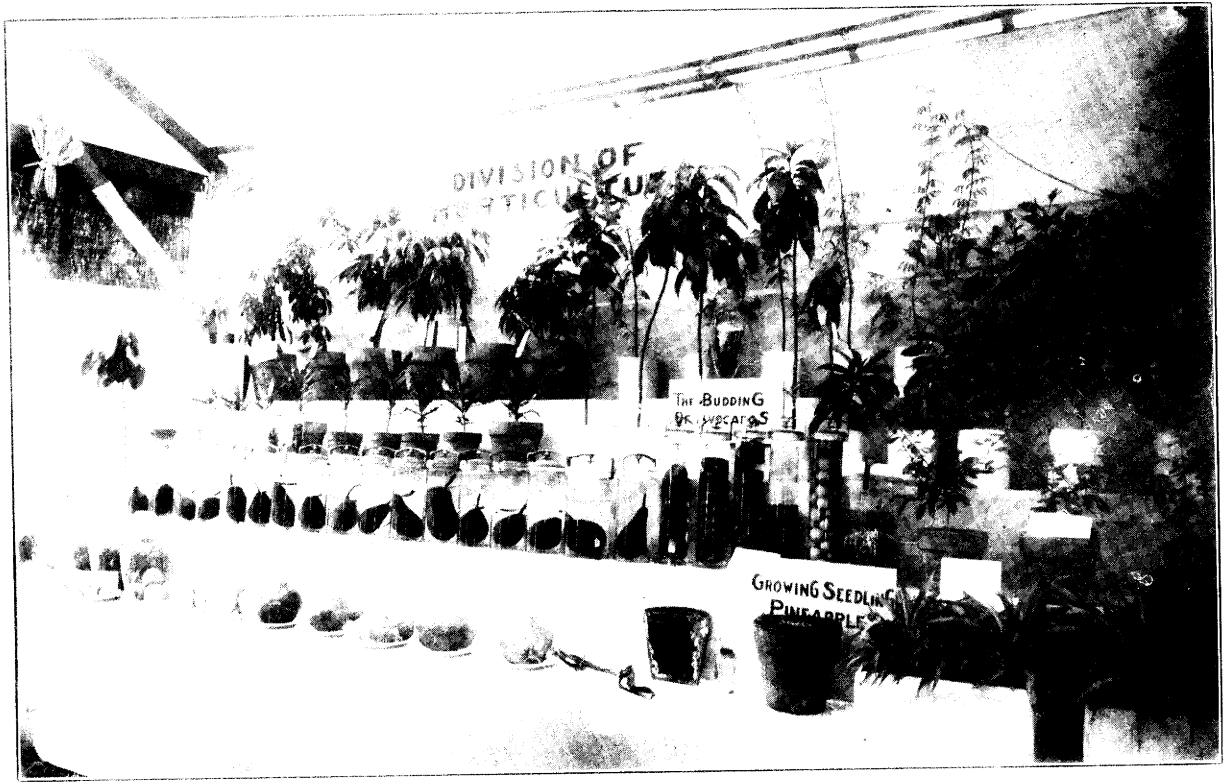


EXHIBIT OF HORTICULTURAL DIVISION AT TERRITORIAL FAIR.

experiments on a small scale have been conducted in pots at the central station. Considerable progress has been made in the determination of the nature of the effect of excess manganese on plant growth.

EXTENSION WORK.

The vital necessity of increased efforts looking to the local production of foods for man and feed for animals has resulted in a marked increase in the activities and responsibilities of the extension division. Cooperative demonstrations, which in former years were arranged for only with considerable difficulty, have been rapidly arranged for in numerous locations, and in many instances it has been impossible to undertake as many of these as desired by various private individuals and concerns which have been interested in the emergency food-crop production work.

A most important advance in the extension work of the islands was the appointment of a number of county agents by the Territorial Food Commission shortly after the outbreak of the war. These agents, provided with automobiles and other means of transportation, have been most effective in bringing home to the producing public the best agricultural practices worked out in the islands. It has been found that numerous isolated farmers have developed practical ideas which are with profit being adopted by the other farmers throughout the islands, the county agents serving as a means of communication between the isolated farmers and bringing about an exchange of valuable ideas. The extension division has cooperated closely with the county agents. The superintendent of extension has acted temporarily as county agent for Maui County and by reason of his wide experience in agricultural extension work has been able to give much helpful advice and information to the other county agents, especially during the first few months of their work.

The demonstrations at Haiku, besides serving the general purpose of demonstration farms, continued to be the source of a great deal of valuable agricultural information. The central station avails itself of the opportunity offered to conduct various experiments on a field scale, thus largely overcoming the disadvantages of conducting all the experiments on small plats. The dependence put in the results obtained at the demonstration farms at Haiku by the leading agricultural companies of the islands as well as by the packing and canning industries speaks well for the permanent and practical value of the work being accomplished.

Much of the success of the agricultural phases of the Territorial fair was due to the inspiring efforts of the superintendent of extension in stimulating interest throughout the islands and thus securing many exhibits which otherwise would not have been made such notable features. In addition, the superintendent also had immediate charge of the installation and general arrangement of the exhibits of the experiment station and of the decoration of the two large tents occupied by the agricultural exhibits. Practically every activity of the experiment station has been made the subject of further experimentation and demonstration on the Haiku farms, and in turn the best and most promising of the practices there worked out and developed have been passed on to the regular collaborators and private cooperators throughout the islands.

PLANT-DISEASE INVESTIGATIONS.

The rapid development of home and school gardens, together with the increased acreage planted to food crops on a large scale, has caused a material increase in the prevalence of various diseases and insect pests. The situation has been met as rapidly as possible through the determination of the most practical means of combating these various troubles. The use of the simplest spray pump and least complicated sprays has been emphasized, especially owing to the mixed population and the necessity of reducing such operations to their simplest possible form.

Probably the most serious disease which developed during the year is that of the banana, designated banana freckle or black spot disease. This has spread so rapidly from the valley in which it was first discovered that at the present time it seriously threatens the entire banana industry. The major portion of the pathologist's time during the coming year will probably be spent in an attempt to formulate a practical means of arresting the spread of this disease.

Another serious trouble was the taro rot, which caused material losses to many of the taro growers of the islands. Through the cooperation of one of the largest land-holding companies of the islands, experiments have been inaugurated looking to the development of practical means of controlling this disease.

The Irish potato continues to be affected by a number of troubles, including the late blight, early blight, mite disease, and tuber moth. Practical methods for control of these troubles have been worked out, and while much remains to be done, it is gratifying to be able to record that marked increases in yields have been repeatedly obtained by growers who have carried out the recommendations of the station.

Field and laboratory observations have revealed the presence of numerous miscellaneous fungus diseases and insect enemies of a great number of economic plants, especially food crops. An annotated list has been prepared and as rapidly as possible the most important troubles are receiving detailed attention.

AGRONOMIC INVESTIGATIONS.

In common with the efforts of the other divisions of the station, the agronomic work was directed chiefly along the lines of the production of forage and feed crops for animals and food crops for man.

The corn investigations have shown the variety introduced from Guam to be very resistant to the attacks of the corn leaf hopper and to give much higher yields than were obtained from any of the strains received from the mainland. The entire seed crop produced by the station is being used for the purpose of increasing the acreage of this strain of corn as rapidly as possible throughout the islands.

The work with the edible canna has been most promising, yields at the rate of over 40 tons of tubers per acre having been obtained 8½ months after planting. The station has made numerous distributions of tubers to individuals who have planted them as temporary ornamental plants in their yards, for the purpose, however, of utilizing them as an emergency food crop in case of necessity. The scarcity of tubers has prevented the planting of any considerable areas to this crop, it having been considered better to start numerous small patches from which additional plantings could be made in the immediate neighborhood of the initial plantings.

The Castner substation continued under the immediate oversight of the agronomy division, although the horticultural division has started some pineapple experiments and the chemical and pathological divisions coöperated in planning and carrying out experiments involving chemical and pathological features. The high percentage of manganese in the soil makes the problem of forage and food crop production very complicated, especially when combined with a low rainfall. Pigeon peas and sorghum appear to be very promising sources of forage. A heavy application of manure enables a number of food and forage plants to make a satisfactory growth in spite of the high manganese content of the soil.

GLENWOOD SUBSTATION.

The policy of the Glenwood substation, as compared with that of previous years, was changed somewhat during the past year. Upon the recommendation of the station, the Hilo Board of Trade appointed a Glenwood substation committee to keep in touch with the needs and activities of the substation and to serve as an intermediary between various interests, agricultural and otherwise, on the island of Hawaii and the Glenwood substation. The agricultural problems of the section in question are numerous and difficult, and the methods of approach are not always clear. The judgment of those having the policies of the substation practically in hand, combined with the counsel afforded by the board of trade committee, has done much to enable the station to carry on its work with a very satisfactory local support.

The increasing importance of food-crop production has led to the placing of additional emphasis on this line of investigations. Numerous varieties of the standard food crops have been placed under test to determine their adaptability to the peculiar local conditions. The poultry flocks continue to occupy a prominent place in the substation's activities, having proved a most valuable and profitable line of work. The trap-nest records of the selected portions of the flocks have been so satisfactory that the demand for hatching eggs has been greater than could ordinarily be supplied. The dairy, having proved unprofitable during a series of years, has been materially reduced in size. The Guernsey bull has continued to give satisfactory results throughout the neighborhood, and his services are being continued.

In addition to the experiments and demonstration work under way at the substation, the superintendent has spent two days of each week doing county-agent work for about 20 miles in each direction in the district surrounding the substation. He has also kept in touch with the work being done by the Territorial county agents in the other sections of the islands.

PUBLICATIONS.

Much of the information acquired by the station has demanded immediate presentation to the public. It is a pleasure to record the hearty cooperation in this work which has been accorded by the local papers throughout the islands in publishing the various articles submitted by the station's staff. Practically without exception the station has prepared each week one or more articles on timely agricultural topics which have been carried by one or more of the local papers. The quick response on the part of the public to such of the articles as suggested calling at the station for additional information or for seeds or cuttings of food plants has been ample demonstration of the promptness with which these messages reached the reading public.

The following publications have been issued by the station during the year:

Annual Report for 1917.
Bulletin 44, The Litchi in Hawaii.
Press Bulletin 53, Composition and Digestibility of Feeding Stuffs Grown in Hawaii.
Extension Bulletin 3, Emergency Series I, Field Production of Beans.
Extension Bulletin 4, Emergency Series II, Methods of Combating Garden Pests.

Extension Bulletin 5, Emergency Series III, Peanuts—How to Grow and Use Them.

Extension Bulletin 6, Emergency Series IV, The Banana as an Emergency Food Crop.

Extension Bulletin 7, Emergency Series V, Drying as a Method of Food Preservation in Hawaii.

Extension Bulletin 8, Emergency Series VI, Bean Spot Disease.

REPORT OF THE HORTICULTURAL DIVISION.

By J. EDGAR HIGGINS.

The unusual conditions brought about by the war, demanding that every energy, not only of the Government but of the individual, be focused upon the one supreme object, have made it necessary to suspend in part the usual investigations looking to the betterment of horticultural practice and the improvement of plants in order to assist in the more immediate application of the best-known agricultural practices to crop production. A maximum production of food is the present necessity, and while the regular horticultural projects have not been lost sight of, much more attention than usual has been given to what may be termed extension activities. The greatly augmented local correspondence and the increasing volume of personal inquiry at the station bear testimony to the enlarged interest in the production of fruits and vegetables.

BANANA PROPAGANDA.

An extension bulletin[1] by the horticulturist on the banana as an emergency food crop had its origin chiefly in this problem of emergency food supply and also in part in the general need for a brief statement of cultural methods, there having been many requests for such information which it has been impossible to supply since the banana bulletin[2] of the regular series has been out of print. One object of the work was to point out some of the possibilities of the banana as the basis of a large and profitable industry which, in the event of the withdrawal of other products, could supply a substitute for the greater part of the farinaceous or starchy foods for the whole of the island population. It is a well-known fact that in many tropical countries the banana is one of the principal food crops of the population, but in Hawaii it is used chiefly as fresh fruit, little attention being given to the many ways of preparing it for the table, while banana flour and banana "figs," or dried fruit, the two most concentrated forms, are practically unknown. The bulletin discusses the production of the banana, its food value per acre yield as compared with other staple crops, some of the various forms in which the fruit may be concentrated, such as banana flour and banana figs, and also the present production and possible increase in plantings in Hawaii.

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[1] Hawaii Sta. Ext. Bul. 6, Emergency Ser. IV (1917).

[2] Hawaii Sta. Bul. 7 (1904).

The banana situation became somewhat complicated during the year when the ships used in carrying the fruit to San Francisco were one after another commandeered for war purposes, thus rendering it impossible to get more than a small portion of the fruit to market. No appliances were at hand to dry bananas or otherwise put them in nonperishable form. The station, through Mrs. J. M. Westgate, had worked out methods some months previous by which baked banana pulp could be mixed with wheat-flour dough, replacing one-third of the weight of the flour. The bread thus made was of excellent flavor, texture, and appearance. Various modifications of this method were devised by individuals and by the large bakeries for the use of bananas in bread, and this was found to constitute an outlet for considerable quantities of the fruit. A campaign for the increased consumption of bananas was instituted by Honolulu business organizations and supported by the local press. These combined efforts were to some degree successful in relieving the congestion of this fruit upon the market and in saving wheat and other imported foodstuffs. The prices received for bananas for such uses, however, were decidedly less than the net receipts per pound on fruit that had been shipped to the mainland. This fact, combined with the prospect of inadequate shipping space for some time to come, has resulted in diverting some of the banana lands to other crops. The present abnormally high price of sugar and the urgent need of all that can be produced tends to cause all suitable lands to be planted to sugar cane.

SCHOOL AND HOME GARDENS.

The horticulturist, as in the year previous, acted as one of the judges of school and home gardens in connection with the prize contests conducted by the Honolulu Star-Bulletin, visiting a large number of the home gardens and all of the school gardens on the island of Oahu several times. The home gardens were so numerous and so widely scattered that it was necessary for the judges to apportion among themselves the work of examination. The best of those reported by the different groups were then seen and compared by the entire board of judges for the awarding of prizes. The importance of this work can not easily be overestimated, for it has resulted in very keen competition and interest in the cultivation of the soil not only at the schools but at the homes. Better still, this interest has been reflected in the general community.

Concerning this work, the Hon. Franklin K. Lane, Secretary of the Department of the Interior, on his visit to Hawaii, spoke in part as follows:

> I have been deeply gratified at the spirit and ability which the Territory's children have put into their gardens and impressed with their realization of the significance of what they are doing.
>
> Through the stimulus given by this early movement, hundreds upon hundreds of gardens have been cultivated in every section of every island, and it is deeply impressive that this year more than 5,000 children were engaged in the Star-Bulletin contest, and, in addition, carried on active work for the Red Cross, for war saving stamps, and Liberty bonds.

TERRITORIAL FAIR.

Another extension activity has been in connection with the First Territorial Fair of Hawaii, held at Honolulu from June 10 to 16, inclusive. In connection with committees on field crops, fruits, and vegetables, and the committee on plants and cut flowers, preparations were made several months in advance to bring together the varied island products in a successful exhibition of large educational value which would serve particularly as an inspiration to greater production. The results, so far as they can be judged at this time, were highly satisfactory, a large and varied collection of products having been presented. Some points were also noted where greater emphasis should be placed at another fair.

Among the horticultural features meriting special mention was a collection of new seedling taros produced by G. P. Wilder, of Honolulu. In view of the importance of the taro plant to the whole archipelago and the failure of the crop in many places, a record should be made here of this, the first attempt, so far as known, to produce seedling varieties resistant to the prevalent diseases or otherwise superior to those that have been long in cultivation. The horticultural division of the station was able to extend to Mr. Wilder its propagating facilities for starting these seedlings, and it desires in every way possible to assist such important work.

A significant feature in the vegetable exhibit was the large number of cucurbitaceous fruits, including squashes and pumpkins grown at comparatively low altitudes. For many years these, with the exception of a few varieties, have been almost impossible of successful production because of the prevalence of the melon fly (*Dacus cucurbitæ*). The large number of specimens shown would seem to indicate that the melon fly's natural enemies introduced by the Territorial Board of Agriculture and Forestry have had an appreciable effect in checking the pest.

In the room occupied by the Hawaii Experiment Station, the division of horticulture presented a number of new plants, including rare varieties of litchi, new selections of algaroba, mate or Paraguay tea (*Ilex paraguayensis*), also roselle, Macadamia nuts and seedling trees, etc. A demonstration of the method of growing pineapple seedlings was made, showing the germination of the seeds and the care of the young plants up to the time when they are ready to be set out in the field. The budding of the avocado was illustrated by a number of trees, showing the different stages from the making of the incision in the stock to the completed process with the stock healed over where it had been cut off above the bud. A collection of tropical fruits in preservative fluid in museum jars was shown, including about a dozen varieties of avocado representing some of the best kinds discovered among the thousands of seedlings growing chiefly on the island of Oahu. Some citrus fruits grown at the station were shown fresh, also fruits of the snake gourd (*Trychosanthes anguina*) and of some of the papayas bred at the station were placed on exhibition and cut from time to time to demonstrate their qualities to especially interested observers (Pl. II).

DISTRIBUTION OF PLANTS.

It is the purpose to confine this work chiefly to dissemination of varieties bred at the station or to new introductions for further trial, as it is not considered the function of the station to send out seeds and plants of varieties easily secured from dealers. Wednesday afternoons and Saturday mornings were designated as distributing hours. There has been a larger demand than in any previous year for seeds and plants of the kinds of papaya and tomato in process of breeding at the station, and many thousands of these have been placed, usually in small allotments. Some varieties of sweet potatoes that had been under observation were placed with the division of agronomy to be disseminated with other varieties which that division had been growing. Several varieties of roselle also have been sent out. In the distributions, emphasis has been placed this year upon such plants as yield a rapid return in food products.

BEAN TESTS.

It is difficult to overestimate the value of beans as a food crop. The high protein content of the dried seeds is well known, and fresh and canned string beans, and also canned lima beans, are becoming more popular every year. Hawaii has produced only a small part of the dried beans that it consumes, and until the season of 1917–18 had never canned beans in any form on a commercial scale. This Territory may well profit by the experience of Porto Rico, that island having changed since the beginning of the war from a large importer to an exporter of beans. There are every year hundreds of acres of land in process of preparation for pineapple planting that would be benefited by the growing of a crop of beans and the plowing under of the vines. After the pineapple plants have been set out, there are several months during which they occupy only a small portion of the land upon which they stand, and it is probable that one crop of a compact, nontrailing variety of beans could be grown between the rows without any injury and possibly with benefit to the pineapples.

The high price of canned string beans in the American markets in the autumn of 1917 attracted the attention of Hawaiian canners. It appeared that Hawaii might produce a crop during the winter season and find a comparatively bare market, and to this end a small acreage was planted and the crop canned. Very few data, however, were available as to the varieties best adapted to Hawaiian conditions, although the experiment station had in part foreseen the need of information and had begun some variety tests. J. H. Cowan, of the horticultural division, began a series of such tests on October 1, 1917, by planting at the station the following varieties: Giant Stringless Green Pod, Stringless Green Pod, Black Valentine, Early Refugee, French Mohawk, Canadian Wonder, Six Weeks, Refugee Wax, Prolific Black Wax, Golden Wax, Ventura Wonder Wax, and Davis Kidney Wax. The first picking was made from these on November 19, the second on November 28, and the third and last on December 6. The data are given below:

Results of variety tests with beans.

Variety.	First picking.			Second picking.			Third picking.	Total weight of crop.	Percentage of total crop[1] stung by melon fly.	Estimated yield per acre.	
	Weight of crop.	Number of pods.	Percentage of pods stung by melon fly.	Weight of crop.	Number of pods.	Percentage of pods stung by melon fly.	Weight of crop.			Total weight.	Weight of sound pods.
	Lbs., oz.			*Lbs., oz.*			*Lbs., oz.*	*Lbs., oz.*		*Lbs.*	*Lbs.*
Giant Stringless Green Pod	12½	69	35.2	2 12¼	224	1.8	1 2	4 10¾	7.5	6,783	6,275
Stringless Green Pod	3 6¼	297	47.02	2 14½	203	5.72	5	6 9¾	21.2	9,534	7,513
Black Valentine	2 ½	219	47.9	2 8½	229	.43	5	4 14	16	7,078	5,946
Early Refugee	2 13½	405	....	4 10½	568	......	1 7¼	8 15¼	....	12,999	12,999
Stringless Refugee	2 0	238	2.1	4 8½	415	......	1 8¾	8 1¼	.76	11,729	11,640
Canadian Wonder	5 1	440	11.11	4 10	417	1.7	11	10 6	5.9	15,064	14,176
Six Weeks	1 13½	174	4.8	2 5½	202	......	12¼	4 15¼	2.1	7,191	7,040
Refugee Wax	1¾	14	....	12	80	......	12	1 9¾	....	2,336	2,336
Prolific Black Wax	2 3¾	234	3.08	3 2	232	.43	1 ½	6 6¼	1.7	9,279	9,122
Golden Wax	2 ¾	213	18.3	2 3	220	.91	1 2¼	5 6	8	7,804	7,180
Ventura Wonder Wax	2 2¾	223	1.36	2 5½	202	......	15¾	5 8	.7	7,986	7,930
Davis Kidney Wax	2 0	193	8.04	2 14	222	......	11½	5 9½	3.6	8,122	7,830
French Mohawk	3 14¾	328	15.9	1 12	257	1.2	9¼	6 4	9.6	9,097	8,224

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[1] On basis of first and second pickings only, no records being available for the last picking, probably because of very slight injury.

It was found that an important factor in successful bean production lies in the susceptibility of the different varieties to the attacks of the melon fly. A careful count was made of the number of sound pods and of those stung in each of the first two pickings. In the last picking no such segregation is recorded, presumably because of the comparatively light infestation. It will be observed that Early Refugee and Refugee Wax received no injury whatever from the fly, the Stringless Refugee (not wax) and the Ventura Wonder Wax have each less than 1 per cent injury, 21 per cent of the Stringless Green Pod was stung, and varying degrees of susceptibility were shown by the other varieties. A noteworthy fact for which no explanation can be offered is that there was uniformly a very much higher percentage of infestation in the first picking than in the second.

The yields recorded in the column "Total weight of crop" are for an area of 30 square feet only, the tests having been begun on a small scale. Acre yields are calculations on this basis. They are valuable not so much in showing what yields may be expected from an acre as in showing the relative yielding power of the different varieties. In the last column, deductions have been made for the injured pods so as to show the relative yielding power of the varieties in terms of sound pods. Among the wax beans, the yield of sound pods is rather uniform in the varieties tested, except in the case of Refugee Wax, where it falls to less than one-third of that of the other varieties, notwithstanding the fact that its competitors suffered more or less severely from melon fly attacks.

The first eight varieties listed in the table are green podded. The Canadian Wonder is the heaviest yielder, but in respect to stringlessness and other qualities requisite in a first-grade bean for canning or for table use, it was not equal to some of the others. After careful tests of cooking qualities, flavor, texture, and absence of strings, it was concluded that the Stringless Green Pod, the Early Refugee, and the Stringless Refugee were of most promise as green beans for canning purposes or for table use under the conditions existing at the station.

Similar variety tests, including also some varieties of Lima beans, were undertaken on a somewhat larger scale in the pineapple lands of Aiea and Halemanu, both on the island of Oahu. Various combinations of fertilizers were applied in plats running at right angles to the rows. It is regrettable that, owing to the distance from the station and the impossibility of giving them continued close attention, these plantings suffered so severely from sudden insect attacks that no accurate data can be given as to the yields. In both cases the insects were cutworms and Japanese beetles which could probably have been completely controlled had the need been known in time.

The Stringless Green Pod appeared to be one of the best at Aiea. The fertilizer plats indicated the need of both phosphoric acid and nitrogen, the best appearing plats both at Aiea and at Halemanu being those to which was applied 1,500 pounds of acid phosphate and 500 pounds of sulphate of ammonia per acre.

TOMATO BREEDING.

The melon fly is the greatest enemy of tomato growing in Hawaii, the tomatoes in the local markets usually having been picked green and allowed to color in the house or store, where flies can not get at them. Such fruits do not attain the natural color and are quite lacking in flavor. As in the case of beans, there are wide differences in susceptibility to fly attack among tomatoes, but all of the large red-fruited varieties introduced and tested here have been found to be quite subject to attack. A small wild-growing sort, doubtless an escape from cultivation, appears to be immune, and a very large degree of resistance or immunity is possessed by the "pear" and "plum" varieties tried. But as all of these are small-fruited sorts, it seems desirable to combine, if possible, the fly-resistant character with the greater size of some of the standard kinds usually grown on the mainland. Mr. Cowan undertook the work of making certain crosses with this aim in view and also to determine, if possible, what constitutes the resistant character. It is regrettable that his work was terminated by Mr. Cowan's entry into military service before completion, but some valuable results were attained which are recorded here.

Flowers of the Earliana were crossed with pollen from the small wild form (Pl. III, fig. 1). The Earliana is a symmetrical, smooth variety, of small to medium size, bearing many of its fruits in clusters, while the small wild form is very symmetrical and round and also bears its fruits in clusters, but it is only about five-eighths inch in diameter. The first generation was variable and intermediate in size between the two parents, but all the fruits appeared to be free from infestation, except where otherwise injured (Pl. III, fig. 1). Several plants were selected, and seeds were taken from these for planting. The second generation also is recorded as having been free from attack at the station, and many thousands of seeds and seedlings of this generation were distributed for further trial. It was not possible to get any accurate record of the behavior in the majority of cases, but many favorable reports have been received, and there has been a strong demand for more plants.

Another cross was the Red Pear×John Baer. The fruits of the former are very small, distinctly pear shaped, and apparently immune to the melon fly, unless the skin is injured by birds, fungus diseases, or other causes. The John Baer is of medium size but is attacked by the pest. The first generation of the hybrid is recorded as practically free from attack, but the second has shown some degree of infestation.

It seems improbable that resistance is due to any single character. By a study of the habits of the fly in confinement with immune fruits it is seen that the female fails to sting the fruit and deposit her eggs because the ovipositor slips on the surface of the skin and can not penetrate. This would appear to be due to a combination of slipperiness and toughness of the skin. With varieties of less resistant fruit, the fly in confinement in the laboratory will make repeated futile attempts to oviposit on various parts of the skin until finally it finds the vulnerable spot, frequently at the point where the stem is attached to the fruit and is covered by the calyx. If there is sufficient flattened area about this point to afford a good foothold, and if at the same time the circle protected by a tightly fitting calyx is not greater in diameter than the length of the ovipositor, eggs are deposited here just at the base of the fruit. A tomato with a slight depression about the stem end is subject to attack at this point, while one such as the Red Pear is difficult or impossible of attack. Again, if a tomato is of very uneven surface or "ribbed" (marked with depressed lines, as is the case with the Ponderosa type), it becomes extremely vulnerable at many points. Very few, if any, of these will escape destruction by the larva of the fly, while those forms that have but one vulnerable point will escape in larger numbers. There may be other elements entering into the problem, but from observations it would appear that any tomato to be bred for resistance to the fly must combine many characters, first, those relating to shape, of which there may be several, and, second, those relating to quality of skin, which must combine toughness with a degree of smoothness amounting almost to slipperiness.

PINEAPPLES.

The pineapple seedlings planted at Kunia, Oahu, in the autumn of 1916 began flowering in the spring of 1918. Several hundred seedlings were planted out in the autumn of 1917 at Waikakalaua in a well-prepared field which was being planted for the second time to the usual variety (Smooth Cayenne). These were thus placed under ordinary field conditions. The soil is rather highly manganiferous, but the fields are regularly sprayed with iron sulphate, which has been universally adopted in Hawaii to overcome the troubles due to manganese. This should give the seedlings a fair chance to demonstrate their suitability to such field conditions. The seedlings and the surrounding plants made practically no growth during the entire cool season, but on the return of warm weather they began, about the latter part of May, to take on green color and to increase in size. This and similar experiences elsewhere point toward the desirability of planting out pineapple seedlings in the spring rather than in the late summer or autumn.

The seedlings at the station propagating yards and houses have been found to be very sensitive to the effects of temperature. In a glass house where they have protection from cold during the winter they will continue to grow and maintain a dark-green color, while plants of the same lot in soil similarly prepared and in the same sort of containers will lose their chlorophyll, take on a pink color, cease growth, and become weak in appearance when placed outside. These results are secured during the winter whether the plants are exposed to sunlight or partly shaded, though they begin to revive with the return of warm weather. Plate III, figure 2, shows two boxes of pineapple seedlings. The larger plants are a fair average of those being grown under glass, while the smaller constitute an equally fair sample of those growing on tables in the propagating yards, but the smaller plants in this case are 13 months older than the others. A thermograph record on the tables in the propagating yards during the cool season tends to run under the line of 70° F. for the greater part of the time, with a frequent rise for several hours of the day to between 70° and 75°, not infrequent falls during the night to between 60° and 65°, and an occasional record as low as 58°. In the glass house the temperature runs about 10° higher than outside, and the hours of lowest temperature of each night and early morning are shortened because the house retains heat. When seedling pineapples have become established in the fields, it has not been observed that they show greater sensitiveness to cold than do the Cayenne plants, but during the first year or more of their development they require considerable heat.

The work of growing more seedlings was continued so far as seeds have been available. Many hundreds of plants are now awaiting transplanting, including some hybrids of Queen×Cayenne, and several hundred more are ready for the first transplanting in the glass house.

REPORT OF THE CHEMICAL DIVISION.

By Maxwell O. Johnson.

Due to the national and local food shortage, much of the more technical research work of the chemical division was suspended during the past year, and attention was devoted to the determination of practical methods for the preservation and utilization of locally grown food crops. Experiments were made in drying Hawaiian food products and also in canning and preserving food crops. A number of feeding stuffs were analyzed, and a summary of all analyses performed by the station was published. Some fertilizer experiments were made with pineapples and bananas. On a trip to the pineapple fields of the West Indies and Florida information was gathered of considerable value to the Hawaiian industry. The investigations concerning the biochemical influence of manganese were continued.

DRYING HAWAIIAN FRUITS AND VEGETABLES.

As drying is the simplest and cheapest method of food preservation, an extensive investigation is being made of the drying of Hawaiian food products. The banana, taro, cassava, sweet potato, edible canna, and Irish potato have been the chief subjects of experiment, as these crops are grown in Hawaii in sufficiently large quantities to make their production at times likely to exceed the immediate demand. An air drier constructed by the station with a capacity of about 150 to 200 pounds of wet material has given good results both in experimental and practical use in drying under Hawaiian conditions (Pl. IV). Experiments in drying the above-mentioned food products with this drier were published during the year.[1] Drying appears a particularly valuable method as applied to cassava, since it eliminates the two most serious objections to this important heavy-yielding food crop, namely, the content of hydrocyanic acid[2] of the fresh roots and their liability to rapid decay due to the moisture contained. Flour made from the peeled, dried cassava root appeared to be very promising as a wheat-flour substitute, as a very fine white flour was secured at low cost of production. A hot-air oven was used to dry the ripe banana, mango, and papaya, these giving dried products of good quality which appear to offer commercial possibilities for Hawaii.

A tower hot-air drier is in process of construction which will have a capacity of about 300 to 400 pounds of wet material. In this drier the air is heated by steam coils and blown over and through the trays loaded with the products to be dried. This drier is a unit which can be multiplied to give any desired capacity in commercial use. A small vacuum drier has been ordered, and this method of drying will also be investigated.

ANALYSES OF FEEDING STUFFS.

Due to the shortage and high prices of feeding stuffs, considerable interest has been manifested in home-grown feeds. In order to assist in developing local sources of supply, a summary of analyses of

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[1] Hawaii Sta. Ext. Bul. 7, Emergency Ser. V (1918).

[2] Hawaii Sta. Rpt. 1916, p. 24.

Hawaiian feeding stuffs was published during the past year.[1] In this bulletin all the analyses of Hawaiian feeding stuffs made by the chemical division of the station were collected and arranged in a table convenient for comparison with standard tables of American feeding stuffs. On the assumption that the digestibility of Hawaiian-grown feeding stuffs is about the same as that of similar American feeding stuffs, a second table was prepared showing the approximate digestible nutrients and also the nutritive ratios for the different Hawaiian feeding stuffs.

TRIP TO THE WEST INDIAN PINEAPPLE FIELDS.

During the months of November and December, 1917, the chemist made a trip to the pineapple fields of Florida, Cuba, the Isle of Pines, and Porto Rico. The leading pineapple growers of the different districts were interviewed and an inspection made of their fields. Much information of interest to the Hawaiian pineapple growers was secured as to varieties, methods of planting, cultivation, fertilization, etc. The material is being prepared for publication as a bulletin of this station. The Abakka pineapple appearing desirable for introduction into Hawaii, steps are being taken for a trial of this variety on Hawaiian soils.

LIMING HAWAIIAN SOILS.

Most of the work on the effect of liming Hawaiian soils has been discontinued for a time. A preliminary report of an investigation of the reaction of Hawaiian soils with calcium bicarbonate solutions was published during the past year,[2] showing the relation of this reaction to the determination of the lime requirements of soils. A rapid approximate method of determining the lime requirements of soils given in this article appears to offer many advantages for routine soil examinations.

FERTILIZER EXPERIMENTS WITH RICE, BANANAS, AND PINEAPPLES.

Experiments have been made in applying dilute solutions of fertilizing salts to rice. Ammonium sulphate was the only treatment to give any notable increase in yield, a result confirming previous work[3] of the station as to the value of ammonium sulphate as a rice fertilizer. In similar spraying experiments with bananas, ammonium sulphate and potassium sulphate solutions stimulated growth. With pineapples, ammonium sulphate solution gave good results on manganese soils. Nitrate of lime produced very good results with pineapples on windward Oahu, but due to war conditions, this fertilizer has unfortunately not been on the market for some time. As only a small amount of fertilizer can be supplied in a single spraying, this method of application does not appear practical except in certain special cases, as on manganese soils where ammonium sulphate can be added to the iron sulphate solution which is already being extensively used for spraying.

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[1] Hawaii Sta. Press Bul. 53 (1918).

[2] Jour. Indus. and Eng. Chem., 10 (1918), No. 1, pp. 31–33.

[3] Hawaii Sta. Rpt. 1907, pp. 67–90; 1908, pp. 65–82; Bul. 24 (1911).

A small fertilizer experiment with pineapples was started in the fall of 1917, in the Waipio district of Oahu. Several insoluble fertilizers were applied singly and in mixtures directly in the heart of young plants. Up to the present time, dried blood at the rate of 250 pounds per acre has given quite striking results. In Porto Rico, "top feeding" the pineapple in this manner with cottonseed meal or dried blood is said to have fertilizing value and also to prevent "sanding." This method has been practiced in Hawaii only to a very small extent, but as a result of demonstration experiments at the station, it is now being quite extensively adopted by the Hawaiian growers.

MANGANESE INVESTIGATIONS.

The iron sulphate spraying treatment developed by this station[1] as a practical means for overcoming the very injurious effects of highly manganiferous soils on pineapples has met with continued success (Pl. V, figs. 1 and 2). Several thousand acres were added during the past year to the 5,000 which were noted last year as being under the spraying treatment.[2] In practice it has been observed that iron must be frequently supplied to the plant during the periods of rapid growth, but that comparatively few sprayings are necessary during quiescent periods.

Methods of treating the manganese soil before planting to supply iron to the plant have thus far given no success, with the exception of the use of stable manure, and in this method it appears that the pineapple is grown on the manure rather than on the soil. In a coöperative field experiment several promising methods of treating the manganese soil have been tried. As investigations have shown that sulphur is slowly oxidized in the soil, flowers of sulphur was applied to the manganese soil at rates of 500 to 3,000 pounds per acre in the hope that by the aid of the acid formed by this oxidation, possibly some of the immense quantity of iron locked up in the soil would be liberated. Additions were also made to the manganese soil, at rates of 1 to 6 tons per acre, of a red, very acid, upland soil containing apparently considerable quantities of available iron. A third

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[1] Hawaii Sta. Press Bul. 51 (1916).

[2] Hawaii Sta. Rpt. 1917, pp. 7, 26.

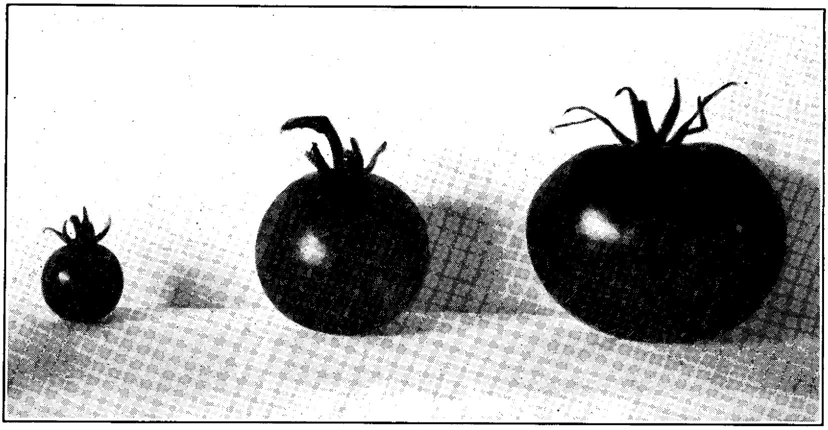


FIG. I.—HYBRIDIZING TOMATOES. WILD PARENT AT LEFT, EARLIANA PARENT AT RIGHT, HYBRID IN CENTER.

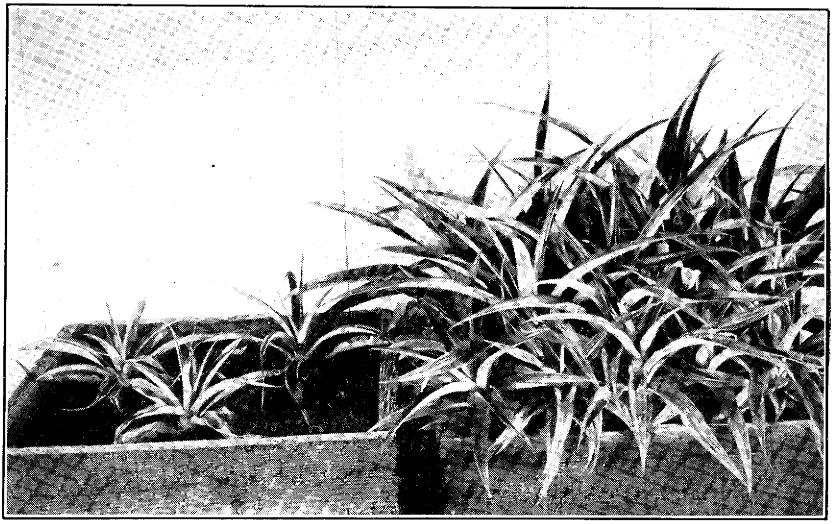
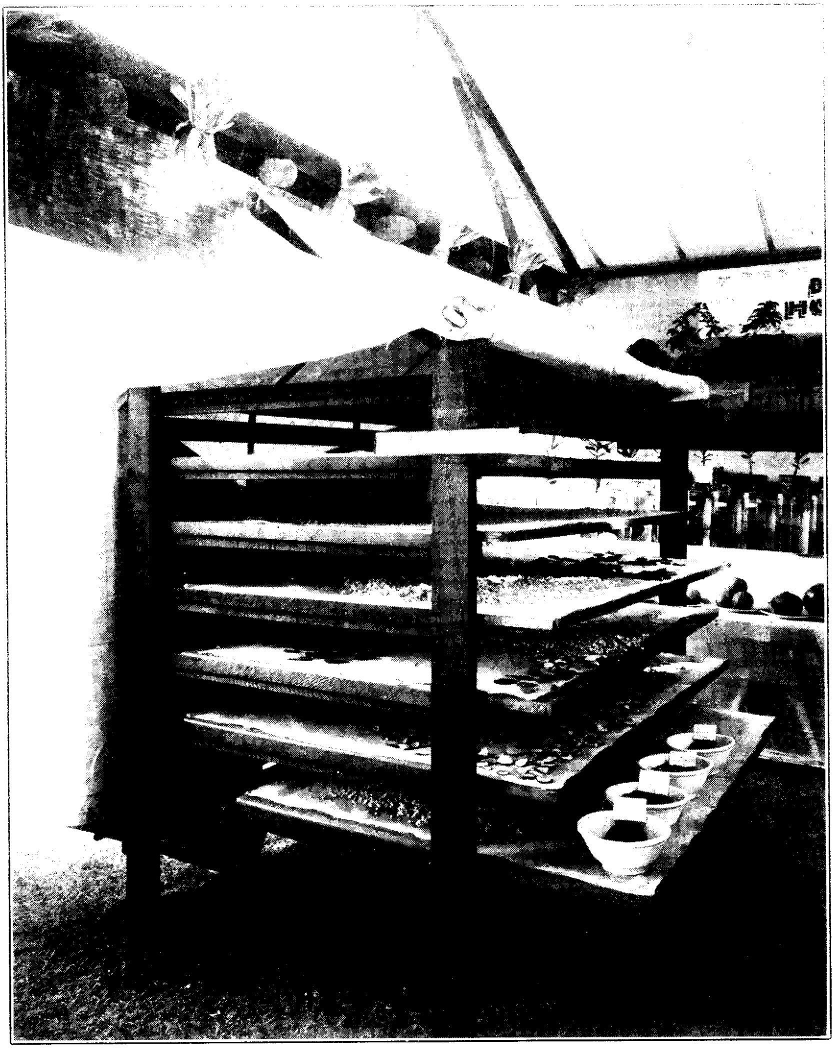


FIG. 2.—EFFECT OF HEAT ON PINEAPPLE SEEDLINGS.

Plants at right grown in glass house during cool season, those at left grown in the open.

PLATE IV.



Air Drier for Vegetables, Showing Process of Drying and Dishes Prepared from Dried Products.

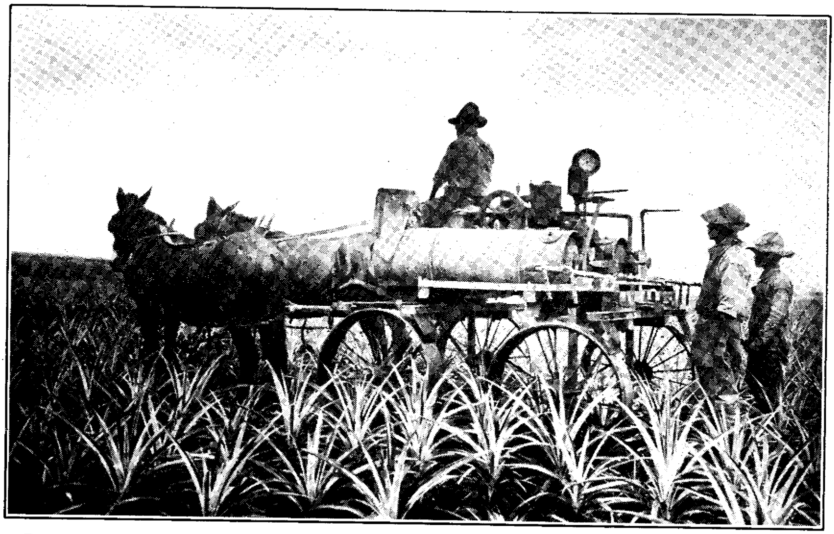


FIG. 1.—HIGH POWER SPRAYER USED FOR TREATING PINEAPPLES WITH IRON SULPHATE SOLUTION.

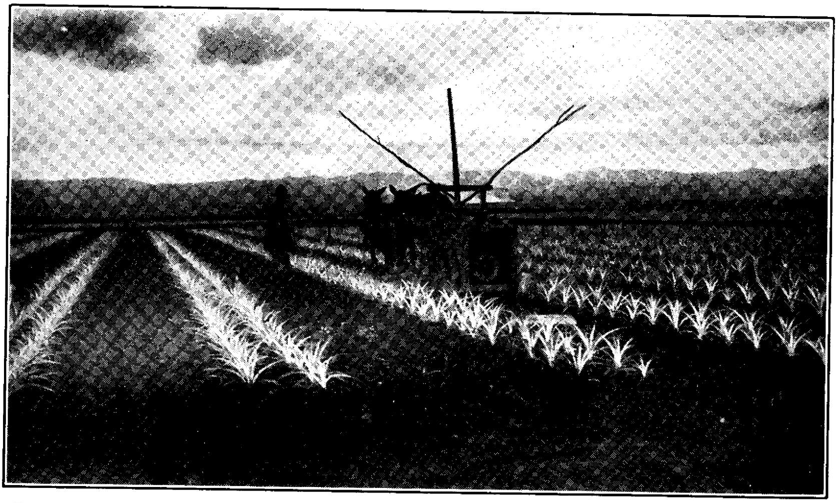


FIG. 2.—MACHINE DEVISED FOR SPRAYING 12 ROWS OF PINEAPPLES AT A TIME.

treatment tried was the application to the soil of bagasse soaked in very strong solutions of iron sulphate. The plants in these experiments, at present about 10 months old, have shown no striking differences as yet between the treated plats and the checks.

Series of experiments were made with rice grown in nutrient solutions to determine the effect of additions of manganese dioxid and of manganous sulphate. Preliminary experiments indicated that the effect of manganese depends largely on the amount of iron supplied by the solution. Accordingly, manganese dioxid was added to the nutrient solution at the rate of 0.4 gram per liter and manganous sulphate at the rate of 50 milligrams per liter, with ferrous sulphate supplied at rates of 5, 10, 20, 40, and 80 milligrams of iron per liter. With the smallest amount of iron supplied, which was, however, sufficient for the normal growth of the checks, manganese dioxid and manganous sulphate caused an extreme depression in growth, the plants in these solutions being light yellow in color with brownish spots. As the amounts of iron were increased up to the very excessive amounts supplied by the highest rate employed, the injurious effects of the manganese were overcome and growth approached that of the checks. Dipping the leaves of the plants at intervals in a dilute solution of ferrous sulphate was also partially effective in overcoming the injurious effects of manganese dioxid. This experiment, repeated with ferric chlorid and with ferric citrate as sources of iron, gave similar results.

Several investigators[1] have claimed stimulated growth as a result of adding manganese to nutrient solutions, but an examination of their work reveals, in most cases, that the effect on growth was determined only by rough measurements of the increase in the height of the plants and that the iron content of the nutrient solutions used was many times that necessary for normal growth and so excessive as to mask the injurious effects of manganese.

Further experiments planned in order thoroughly to check the results obtained have been temporarily held in abeyance by the emergency conditions at present prevailing.

PINEAPPLE WILT.

Serious trouble continues to be experienced with this disease in Hawaii. Burnt lime has been partially effective but can not be considered entirely successful in controlling wilt. In pot experiments a yellowish-brown soil was used on which in the field practically every plant had wilted. Under the well-drained conditions in pots no wilt occurred in any of the pots, even the untreated ones. The plants in the untreated pots showed a tendency to "grow out" of the soil and had only a few surface roots alive. Plantings made in a manganese soil under similar conditions had a very extensive root system. The best means for control of wilt at the present appear to be application of burnt lime before planting, planting in a single-row system on gentle ridges, keeping the soil well hilled up about the base of the plants, and applying air-slaked lime or a mixture of air-slaked lime and reverted phosphate in the heart of the plant.

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[1] Loew, O., and Sawa, S., On the action of manganese compounds on plants, Bul. Col. Agr. Tokyo Imp. Univ., 5 (1902–3), pp. 161–172; Pugliese, A., Sulla biochimica del manganese, Atti R. Ist. Incoragg. Napoli, 6. ser., 65 (1913), pp. 289–315.

REPORT OF THE EXTENSION DIVISION.

By F. G. Krauss.

The results of the work of the extension division during the past year were very satisfactory. It is gratifying to record increased interest in the work of this division on the part of practically every industry in the islands, the sugar and pineapple plantations, as well as the ranches, cooperating more closely than ever in the establishment of diversified agriculture in the Territory. The implement dealers and fertilizer manufacturers are also cooperating, while there was noted a marked tendency on the part of merchants to give increased preference to island-grown produce rather than to imported foods. During the year the superintendent of extension work has devoted about one-third of his time to extension and demonstration trips throughout the various islands, the balance of his time being spent in active charge of the Haiku substation (Pl. XI, fig. 1.)

COLLABORATORS AND COUNTY AGENTS.

Two additional homesteaders collaborated with the station during the year, John H. Midkiff at Kealakekua in the Kona homestead district on Hawaii and J. Anjo in the newly opened Haleakalea tract on Maui. The employment of collaborators in the various districts to serve as representatives of the division and to demonstrate on their own farms the most approved agricultural practices is proving a very satisfactory method of bringing the desired agricultural truths home to the farmer. There are now three collaborators on Hawaii and one on Maui, in addition to the substation and demonstration farms at Haiku in direct charge of the superintendent of extension. There is also one collaborator on the island of Kauai, while the island of Oahu is provided for by the central experiment station at Honolulu and the substation at Castner. Plans are under way for the establishment of a collaboratorship on the island of Molokai.

The work of the collaborators forms an important link in the agricultural-extension chain. Usually the collaborator has some demonstration work in progress on his farm, which is frequently the headquarters for supplying new and tested seeds and cuttings to the neighboring farmers. In this connection it may be mentioned that John de C. Jerves, the collaborator at Kalaheo, Kauai, has distributed more than a million cuttings of the now famous Madeira or Kauai sweet potato, which he was instrumental in bringing to the attention of the producing and consuming public.

The work of J. E. Gamalielson, collaborator at Kaumana, near Hilo, Hawaii, is especially noteworthy. He took over the management of the Glenwood Creamery Co., a cooperative organization of dairy farmers established through the efforts of the Glenwood substation, in August, 1913. A brief history of this cooperative effort, covering the five years of its existence, is given below, having been prepared by him:

> A summary of business transacted by the Glenwood Creamery Co. year by year is presented for the five years of its existence. A beginning having been made the first of June, 1913, May 31 in each succeeding year has herein been considered as the end of the year.
>
> In 1913, F. A. Clowes, then superintendent of the Glenwood substation, built and equipped a creamery at the substation for the purpose of assisting the farmers in the district to produce a good, marketable grade of butter and to find a market for it. After having operated the creamery for some months as part of the work of the substation, paying for the cream according to the butter fat contained in it and making and marketing the butter as the property of the substation, he made arrangements for and called a meeting of the farmers interested, which meeting was held on May 22, 1913.
>
> The farmers then agreed to take over the operation of the creamery and have it operated for them on a cooperative basis and the product marketed the same way, each one to pay into the treasury of the concern $10 for each cow from which to furnish cream, to be paid in 10 monthly installments. The total amount so subscribed was $1,050. Interest-bearing notes were given for the respective sums subscribed and the secretary was authorized to deduct the monthly installments from what became due each of the respective subscribers each month, until the full amounts subscribed had been collected. This was to furnish working capital, as some additional equipment and an addition to the creamery building were needed. Mr. Clowes consented to remain secretary and manager for the concern, which he did until the end of August, at which time J. E. Gamalielson, of Kaumana, was elected secretary, as he lived nearer the market and it was considered easier for him to attend to the marketing, billing, collecting, and remitting to each man his share of the proceeds. Mr. Clowes remained in charge of the creamery and superintended production.
>
> At the time the farmers took over the creamery, butter was selling at 45 cents per pound, wholesale, but about that time Australian butter was coming in and selling as low as 28 cents per pound, and the farmers were forced to discontinue operation of the creamery at the end of November, the same year, but each man made his own cream into butter which was marketed cooperatively.

Summary of business of the Glenwood Creamery Co. for the five years of its existence.

Year.[1]	Amount of butter marketed.	Average price per pound.	Total returns.	Cost of marketing.	Percentage of cost.
	Pounds.	*Cents.*			
1913-14	12,580	41.55	$5,234.56	$300.00	5.73
1914-15	12,683	35.78	4,534.38	291.19	6.5
1915-16	11,314	35	3,965.38	312.75	7.75
1916-17	5,174	38.35	2,036.46	122.92	6
1917-18	4,276	52.8	2,257.76	117.50	5.2
Total	46,027	39.16	18,028.54	1,144.36	6.35

[1] Each year ending May 31.

The falling off in production was caused by competition with imported butter, a number of farmers finding dairying unprofitable and giving it up. Later on the high cost of feed and labor forced them to do without grain feed, to milk only the best of the cows, and to let the others suckle the calves. Some of them had to leave the butter making to the women and children and go out to work for wages in order to meet the constantly increasing cost of supporting their families. At present, with better prices for the product, more butter is being made, but the demand for it being better more of it is being sold near where it is made and is not recorded here.

The cost of marketing covers salaries and telephone rent. Freight charges, which come to from one-half to two-thirds of a cent a pound, according to distance and amounts shipped, are not included.

In addition to his duties as secretary of the cooperative creamery, Mr. Gamalielson operates a successful dairy farm of his own. So far as is known, there is here installed the only set of mechanical milkers in the Territory. In addition to the dairy, a large flock of poultry is maintained, and skimmed milk is utilized to a large extent by the poultry. Both the dairy herd and the poultry flocks are fed largely from farm produce. The total area of Mr. Gamalielson's farm is 74 acres, of which 20 acres is classed as agricultural. This has recently been planted to sugar cane, and the remainder is rough pasture land of which a few acres has been planted to crops for the live stock and the household. Mr. Gamalielson's net average income during the past three years has been about $1,000 annually in addition to his living expenses.

John de C. Jerves, at Kalaheo, Kauai, is field foreman for the Kauai Fruit and Land Company and owns a five-acre homestead at Kalaheo. No one has better demonstrated the agricultural possibilities of a small tract of land well tilled than has Mr. Jerves. The most noteworthy individual activity on his part has been the introduction and distribution of the Madeira sweet potato throughout the islands. No variety is more widely planted now, nor has any other commanded a higher price on the Honolulu market. During a period of temporary overproduction of potatoes in certain seasons of the year, Mr. Jerves has experimented with the feeding of the sweet potato to work mules, cattle, and swine. He finds that the feeding value of this crop, based on present feed prices, is approximately $20 per ton. Since the yield from a 6 to 8 months' crop is about 8 tons per acre, it will be seen that the potato may be made profitable as stock feed alone. Mr. Jerves was visited by the superintendent of extension work during June, 1918, and was found to be encouraging the production of corn, beans, and other crops by both small and large growers throughout the island of Kauai.

In the Waimea homestead district Alexander Arthur was appointed collaborator in 1916. Being one of the earliest settlers, he has a well-established diversified farm of approximately 80 acres. Mr. Arthur has been a successful corn grower and swine raiser. Potatoes, dryland taro, and beans succeed well, and his farm is becoming more and more a valuable demonstration unit.

The newly established collaboratorship at Kealakekua, to which John H. Midkiff was appointed in 1918, is centered in the thriving agricultural district of North Kona. Here many of the small homesteads were first opened for settlement. One of the main objects in establishing a demonstration unit at this place was to test new and promising crops under the direct supervision of the extension division. Mr. Midkiff is a graduate of the animal husbandry course of the University of Illinois. His interest in animal husbandry is indicated by his maintenance of a public service boar for the benefit of the hog raisers of the community. He has also established a free market at Kealakekua where the small farmer brings his produce for sale every Saturday.

The collaboratorship established in the newly opened Haleakalea homestead district on Maui in February is an attempt to help the new settlers from the beginning. J. Anjo, who has been closely identified with the opening of these lands and who has the interest of the settlers at heart, was considered the most suitable person to undertake the work in hand. Through the commendable community spirit shown by the settlers, 40 acres of the demonstration unit was broken up and has had two harrowings and a second plowing. A third plowing and disking will be necessary for the initial plantings of pigeon peas and Japanese cane to demonstrate their value for feeding purposes and to serve as temporary windbreaks until trees can be established. The establishment of this demonstration unit by the Territory marks an important advance in the development of the various homestead districts throughout the islands in that it recognizes the necessity of preliminary experiments and demonstrations for the benefit of the new farmers who take up the homesteads, often without the necessary capital to justify them in making what may prove costly experiments in crop production. The different districts vary so greatly as regards soil and rainfall that what succeeds in one section is little or no indication as to what will succeed in a neighboring locality. This clearly indicates the necessity of preliminary work on the part of the extension and demonstration organizations of the islands.

Through the cooperation of the Haleakalea ranch, in the center of whose holdings is situated the Haleakalea homestead tract, the demonstration farm has been enabled to fence a part of its land. The most urgent need of this enterprise is financial assistance, either from the county or Territorial Government, for the completion of the fencing and the erection of a group of farm buildings consisting of a small residence, barn, and outhouses. The entire expense of the necessary equipment, which in itself would prove a valuable demonstration in efficient and economical building, should not exceed $2,500.

COOPERATION WITH TERRITORIAL COUNTY AGENTS.

The 1917 session of the Territorial legislature provided for the employment of a number of county agents throughout the islands. The closest sort of cooperative relationship has been in effect with these county agents. During the greater part of the calendar year 1917, the superintendent of extension work acted largely in the capacity of county agent for his particular district. He has also kept in close touch with the various county agents throughout the islands and has been of great assistance to them.

The following are abstracts from the report of the superintendent of extension work while acting as county agent for Maui for the period July 1, to December 31, 1917:

> Total farms visited 108. Some of these were visited bimonthly, over 500 distinct visits having been made by the county agent and his assistants during the period of six months covered by this report.
>
> More than 5,000 miles was traveled by automobile, and about 800 miles on horseback.
>
> More than 100 acres of potatoes was sprayed for blight and insect pests.
>
> Twelve thousand pounds select seed potatoes was distributed for the improvement of the potato crops in Kula and Makawao regions.
>
> Three thousand packets of seed were distributed, most of these being of new and improved varieties grown at the Haiku substation.
>
> More than 80,000 sweet potato, cane, and cassava cuttings were distributed from the Haiku substation.
>
> A large amount of agricultural and food commission literature was distributed. Weekly agricultural letters have been prepared for the press, about 30 such articles having been published during the half year. Several talks on agricultural subjcts were also given before good sized audiences.
>
> Plans for several agricultural projects have been prepared for private enterprises. In a number of cases the complete equipment will represent the outlay of thousands of dollars.

The bean-canning projects now under way are largely the outcome of the county agent's endeavors, and may result in the development of an important industry in the near future.

Numerous visitors have called at the substation and demonstration farms.

The correspondence and personal consultation with both large and small farmers have been extensive.

EXTENSION BULLETINS.

Supplementing the general agricultural propaganda of personal visits by the station and extension division staffs, extension bulletins were issued during the year[1] on the field production of beans, methods of combating garden pests, how to grow and use peanuts, bananas as an emergency food crop, and bean spot disease.

In addition to the above, numerous articles have been prepared for the local press in which practical subjects received immediate attention and reached a wide circle of readers. A number of talks on agricultural subjects were given in the rural communities by various members of the staff.

FIRST TERRITORIAL FAIR.

The various activities of the extension division were featured at the Territorial fair held June 10 to 16, 1918 (Pl. VI). The extension division exhibited its seed-selection work with potatoes, its home-grown concentrates for stock feeding, its seed-corn selection work, and the production of substitutes for wheat flour. In addition to this, a series of photographs showed the work in progress on the farms of the various collaborators throughout the islands.

EXTENSION OF NEW VARIETIES OF CROPS.

Special emphasis has been laid on the importance of obtaining the proper varieties of field, forage, and green-manuring crops. High yields of field corn were produced during the past season, notwithstanding the exceptional drought through which the crop was forced to pass. A considerable portion of the farm at Haiku produced shelled corn at the rate of 77 bushels per acre. The variety now exclusively grown on the demonstration farms is the New Era, a 100-day yellow dent corn developed by the extension division by hybridizing Gold Standard Leaming, Reid's Yellow Dent, and Funk's Ninety Day. This variety, which is each year growing in favor, during the past season was planted on 100 acres on the island of Maui. At the recent Territorial fair the first and second prizes for the best ear, and the first prize for the best 100 pounds of shelled corn were awarded to this variety. About 500 pounds of selected seed has been distributed during the past three years, and a considerable seed trade is being developed for this variety by the corn growers on Maui.

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[1] Hawaii Sta. Ext. Buls. 3, 4, 5, 6, and 8 (1918).

The Japanese cane introduced by the extension division some years ago is each season increasing in general favor, no forage crop having withstood the severe drought of the last season better than this cane. One-half million cuttings have been distributed during the year to interested dairymen.

Cowpeas and velvet beans continue to be important crops, and are more extensively planted each season.

Perhaps the most promising crop now under cultivation at the Patterson demonstration farm, Haiku, is the 15-acre field of pigeon peas (*Cajanus indicus*) of the variety New Era. This planting was made in March, 1917, as an intercrop between corn rows. While the drought almost ruined the corn crop the pigeon peas continued to thrive and yielded heavy crops of both seed and forage. A quantity of the seed has been sold in advance for $200 per ton, while the cured forage with pods attached is bringing $40 per ton in the field. Meal prepared from the whole plant has been fed extensively and with satisfactory results to work mules, milch cows, and swine. It seems very probable that hundreds of acres will be planted to this crop during the coming season. The pigeon pea is to the poor dry waste lands what alfalfa is to the rich moist bottom lands of Hawaii.

LIVE-STOCK FEEDING PROBLEMS.

In connection with the development of the extension division farms at Haiku, Maui, constant effort has been made to maintain a balance between crops, live stock, and labor, it being realized that it is essential at the present time to make greater and greater efforts to conserve food, fertility, and labor. As a result of this policy the live stock has been built up until now there are 6 work mules, 4 milch cows, 100 laying hens, and a herd of about 40 head of swine, which are maintained on the 100 acres comprising the two demonstration farms. No produce leaves these farms except the selected seed used for the purpose of extending the improved varieties. The cull seeds, straw, and forage are fed on the place. There is no waste. The manure from the cattle is conserved and has added not a little to the fertility of the land. Vegetable matter not utilized as feed is plowed under as green manure. The labor has been equalized by the development of diversified projects until the working force is now of uniform size throughout the year, thus resulting in greater efficiency and economy. As an outgrowth of the experiments in regard to growing, milling, and feeding of home-grown concentrates conducted at the Haiku substation during the past three years, there has been developed in the past year at the Haiku ranch of the Maui Agricultural Co. a plant for the preparation of 10 tons of mixed home-

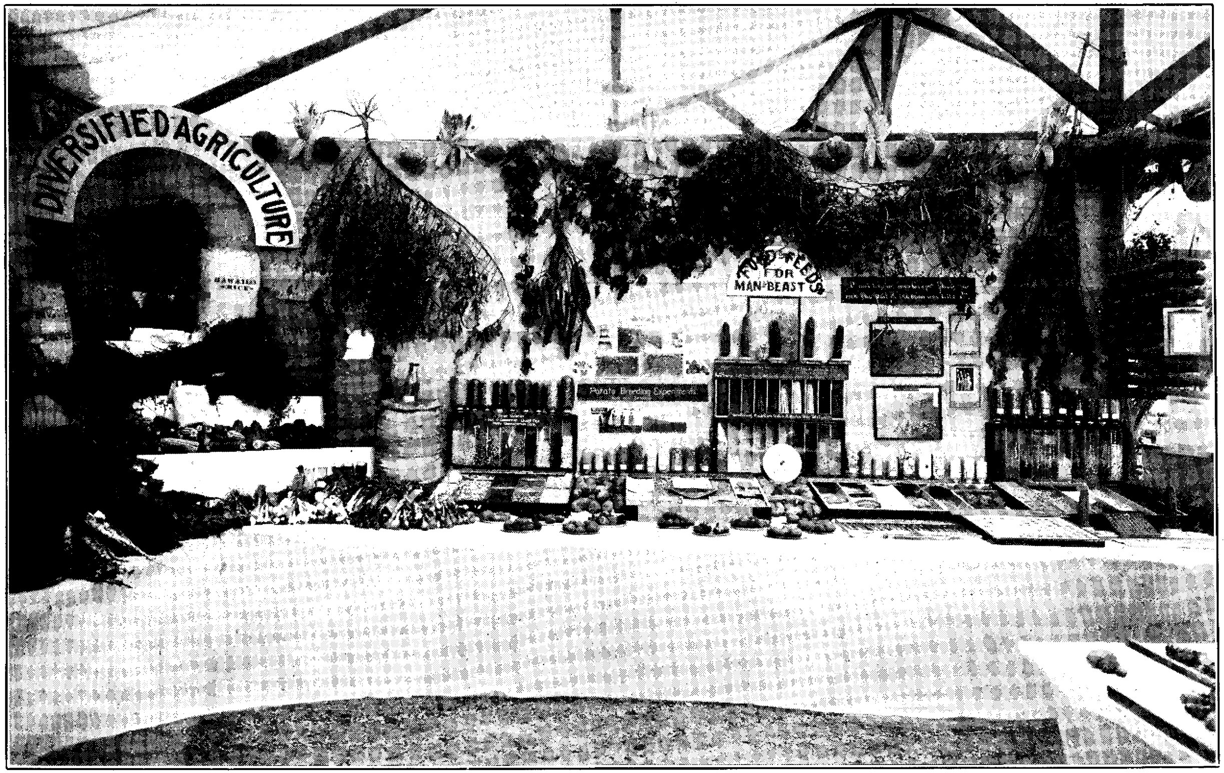
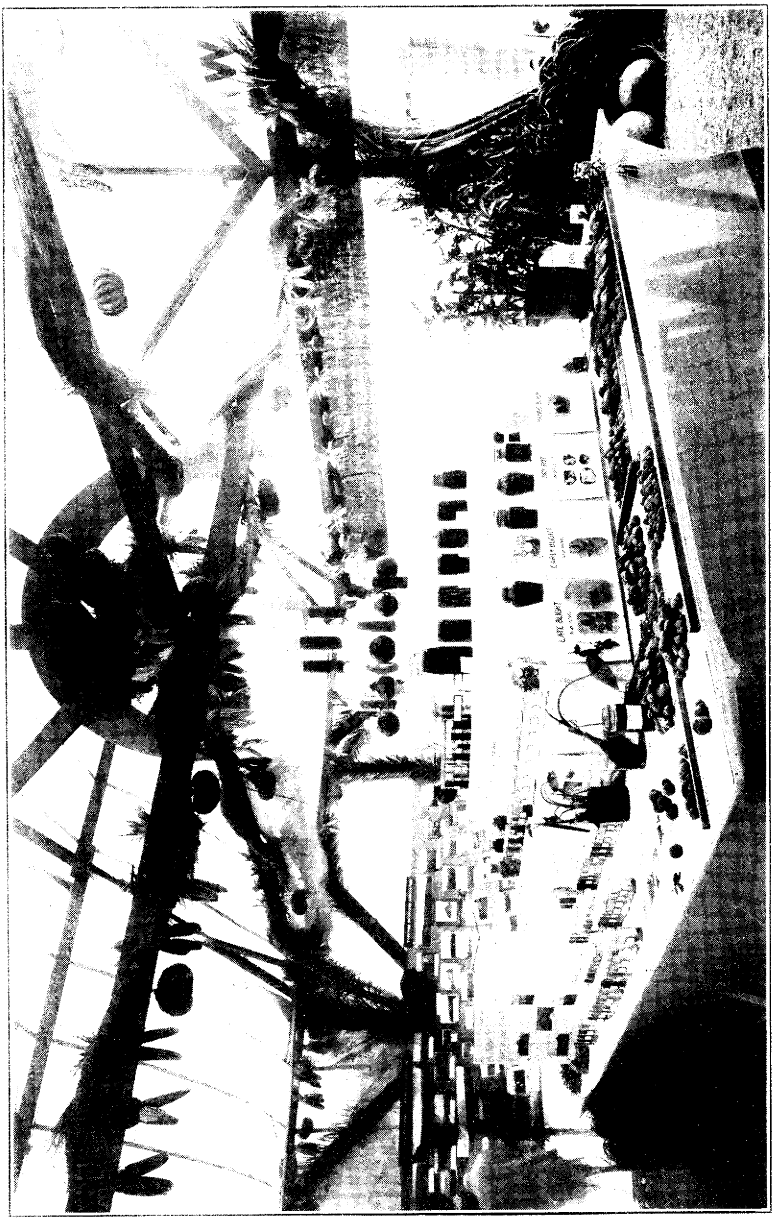


EXHIBIT OF EXTENSION DIVISION AT TERRITORIAL FAIR.



EXHIBITS OF PATHOLOGICAL (RIGHT) AND CHEMICAL (LEFT) DIVISIONS AT TERRITORIAL FAIR.

grown milled feed daily. This is designed to supplant the imported grain formerly required to feed the 1,000 head of work animals owned by the company in question

TRUCK CROPS.

During the past year, in cooperation with the Haiku Fruit and Packing Company an acre was planted to five varieties of string beans and an acre to different varieties of Lima beans. From these plantings the best varieties of each type, both for canning purposes and for yield, were determined. A representative from one of the largest mainland packing and canning concerns pronounced the Maui Red Kidney bean superior to the old Standard Refugee, Improved Stringless, and Kentucky Wonder. Among the Lima beans, the Fordhook and a special selection made by the extension division were considered the best of the five under test as regards suitability for canning.

Some progress has been made in the development of a new type of kidney bean for use where dried shell beans are desired. This work has resulted in the development of a variety which has been named the New Era Copper Kidney and which has yielded 40 per cent more beans under field conditions than any other of the numerous varieties under test. The quality also appears to be excellent.

Following up previous comparative trials of bean varieties, 100 sorts were under test during the past season, and a number of selections have been made and several crosses effected. These were shown at the recent Territorial fair, both as preserved specimens in the pod and as shelled seed.

The second annual test of some 20 varieties of onions has been completed. As in the previous test, the Bermuda type is far in the lead as to earliness, quality, and yield. However, several other varieties of long-keeping quality are giving promise, and it is believed that some may overcome the drawbacks of the Bermuda varieties.

Potatoes continue to form an important crop at the substation and demonstration farms. The third year of hill selection, both for increasing yields and obtaining a blight-resistant type, has shown some success. The fall crop of potatoes was exceptionally good where liberal applications of phosphate were made, especially in connection with the hill-selected seed. A yield of 180 bushels of marketable potatoes was obtained from one acre of Dibble's Russett, as compared with 100 bushels to the acre from unselected seed. At the present writing 23 varieties of potatoes and many selections are under test. The late blight is held in check by spraying with Bordeaux mixture. The potato industry is becoming more and more affected by the potato mite. Fortunately, lime-sulphur spray, or even sulphur alone in the proper form, is proving an effective remedy.

Much credit is due C. W. Carpenter, pathologist at the station, for the discovery of the nature of this new pest and a simple means for its suppression.

THE HOME VEGETABLE GARDEN.

The home vegetable garden has always been an important adjunct to the work with field crops at the demonstration farms at Haiku. An asparagus bed has been maintained for three years. Upland taro in several varieties is grown for household use. String beans and Lima beans are all-season crops, and a great variety of garden vegetables is grown to a less extent.

MISCELLANEOUS ACTIVITIES.

Several planting charts for field crops and vegetables have been prepared by the division for the Territorial Food Commisison, school garden officials, and others. The superintendent has also acted as judge for both the Star-Bulletin garden contest and the Maui County Fair Association garden contest. Several thousand packets of vegetable seed have been distributed where it was felt that the greatest good could be realized.

COOPERATIVE EXPERIMENTS WITH PINEAPPLES.

While the substation at Haiku since its inception has maintained a series of experiments with pineapples because of its location in an important pineapple region, it has only during the past year inaugurated an extensive project looking to the solution of the very important problems which have arisen in this industry, the importance of which is second only to that of sugar. Ten acres of pineapples is now being devoted to cultural, plant type, and fertilizer experiments with this crop. Much interest is being shown by the pineapple growers and packing companies in these experiments, and cooperation with the large pineapple companies is doing much to facilitate the progress of this work, which must necessarily take several years to complete. A number of duplications of the experiments are being voluntarily carried out by private growers, thus furnishing a source of additional data as to the response of the pineapple plants on different soil types and in different locations.

FERTILIZER DEMONSTRATIONS.

The use of superphosphate and reverted phosphate as fertilizers has shown remarkable results. The soils at Haiku show little or no benefit from lime, nitrogenous fertilizers, or potash. The use of phosphate fertilizers, however, in conjunction with green-manure crops, has given extraordinary increases in the yields of alfalfa, corn, potatoes, beans, and onions. As an indication of the value of this work, it may be mentioned that 50 tons of these phosphate fertilizers have been used during the past year in the Haiku district alone, where previously less than a ton had been used, except as an ingredient of high-grade complete fertilizers.

REPORT OF THE DIVISION OF PLANT PATHOLOGY.

By C. W. Carpenter.

In the work of the year in the division of plant pathology, emphasis was placed on food conservation through the control of plant diseases and insect pests. In the interest of extension and demonstration work, field trips were made to all the principal islands of the Territory. The extension phase of the work was considered of paramount importance during the present emergency, and research on problems not promising prompt returns in food conservation is necessarily being held in abeyance. (Pl. VII.)

Throughout the Territory there has been a general awakening to the serious losses induced by plant pests and to the urgent need of practical control measures. The advice of the pathologist has been repeatedly sought in this emergency, and his suggestions have been faithfully carried out by the growers of food crops. The area in diversified crops was greatly increased during the year, mostly through the improvement of waste lands and the use of lands lying fallow. With those engaging in gardening for the first time in the islands, no doubt in some cases errors in judgment have led to the selection of unsuitable situations, but in the majority of cases coming to the attention of this division the failures reported were due to fungus and insect pests. Perfection in gardening was not to be expected in the first attempts, and while acquiring a knowledge of vegetable growing much has been learned of the habits of insect and fungus enemies which will be of value in the future.

The pioneer work started in 1916 by the pathologist in demonstrating insect and fungus pest control methods was continued on a much more extensive scale by the county agents. During the six months beginning with October, 1917, instructions regarding spraying were given by the county agents to 587 Japanese, 169 Chinese, 251 Hawaiians, and 639 Caucasians. In the same period, 181 demonstrations were made. The growers are coming to realize the nature of their difficulties, and enthusiasm is gradually replacing the suspicion and indifference with which the station's efforts were received in 1916. It is the aim of this division to cooperate with the county agents rather than with individuals, and all parts of the islands are now being reached promptly by station propaganda.

PUBLICATIONS.

To meet the increasing demand for information on the part of emergency gardeners, extension bulletins[1] were published on methods of combating garden pests and on bean spot disease. In the manuscript of a bulletin on the diseases of the Irish potato in Hawaii, now practically completed, the large number of diseases which affect the potato crops are described and illustrated, and methods are suggested for the amelioration of conditions. Numerous popular articles on plant diseases were contributed to the local press. During the year an article on the mite disease of potatoes was submitted for publication,[2] and an article on The Wilt Diseases of Okra and the Verticillium Wilt Problem, embracing work completed by the writer at Washington prior to coming to this station, was written and published.[3]

BANANA FRECKLE OR BLACK SPOT DISEASE.

The black spot disease of banana, mentioned in the report of this division for 1917, has spread rapidly during the year and is now a serious trouble in practically all the plantations of Chinese or dwarf bananas (*Musa cavendishii*), on the island of Oahu. The bunches of fruit from badly affected plants are undersized, discolored, and unevenly ripened, thus possibly being subject to fruitfly attack, and unsuitable for export, bringing on the local market only one-fourth to one-half the price of normal bunches. A year ago this disease appeared to be confined almost exclusively to the valley of Kalihi, where it was serious, but it could scarcely be found in Manoa Valley, 5 miles distant. It is now present to an alarming extent in the plantations of Moanalua, Pearl City, Mokuleia, and Kahaluu, as well as in Kalihi and Manoa. During a recent trip to Kalihi Valley, it was impossible to find a bunch of fruit not affected.

The Hawaiian freckle or black spot disease of the leaves and fruit (Pl. VIII, figs. 1 and 2) appears to be entirely different from the banana leaf black spot disease of Jamaica described by Ashby.[4] For this reason and to avoid confusion, the name "freckle" is suggested for the Hawaiian disease.

Whether this is a new disease in Hawaii can not be decided, though the writer inclines to this view. Somewhat similar spots originating in various ways on green fruits have been noted by the growers for a great many years. The injury caused by the red spider may be confused with the early stage of the freckle disease. The writer

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[1] Hawaii Sta. Ext. Buls. 4 and 8 (1918).

[2] Phytopathology, 8 (1918), No. 6, pp. 286–288.

[3] Jour. Agr. Research [U. S.], 12 (1918), No. 9, pp. 529–546.

[4] Ashby, S. F. Banana diseases in Jamaica. Bul. Dept. Agr. Jamaica, n. ser., 2 (1913), No. 6, pp. 109–112.

PLATE VIII.

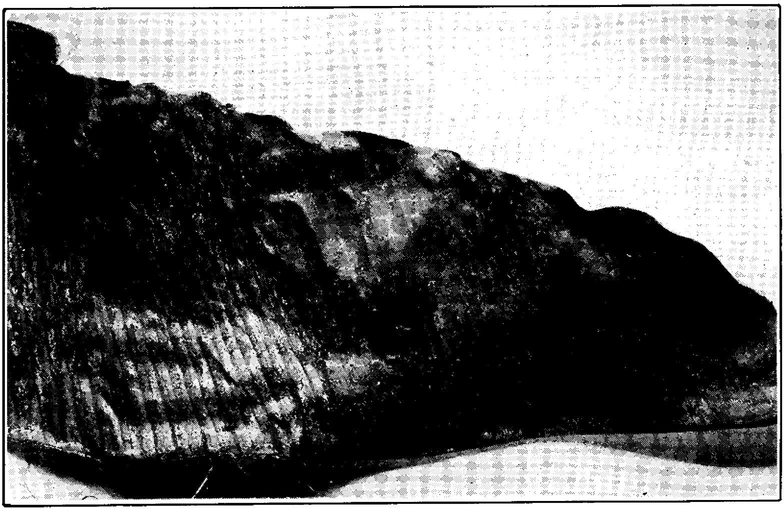


FIG. 2.—PORTION OF BANANA LEAF, SHOWING FRECKLE DISEASE.

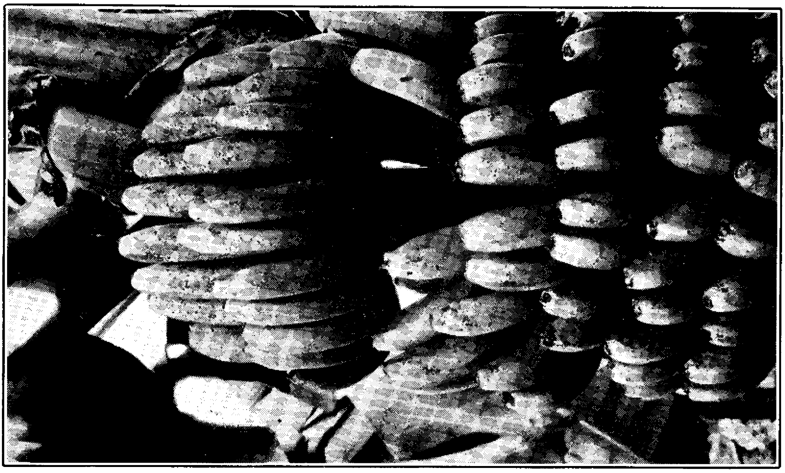
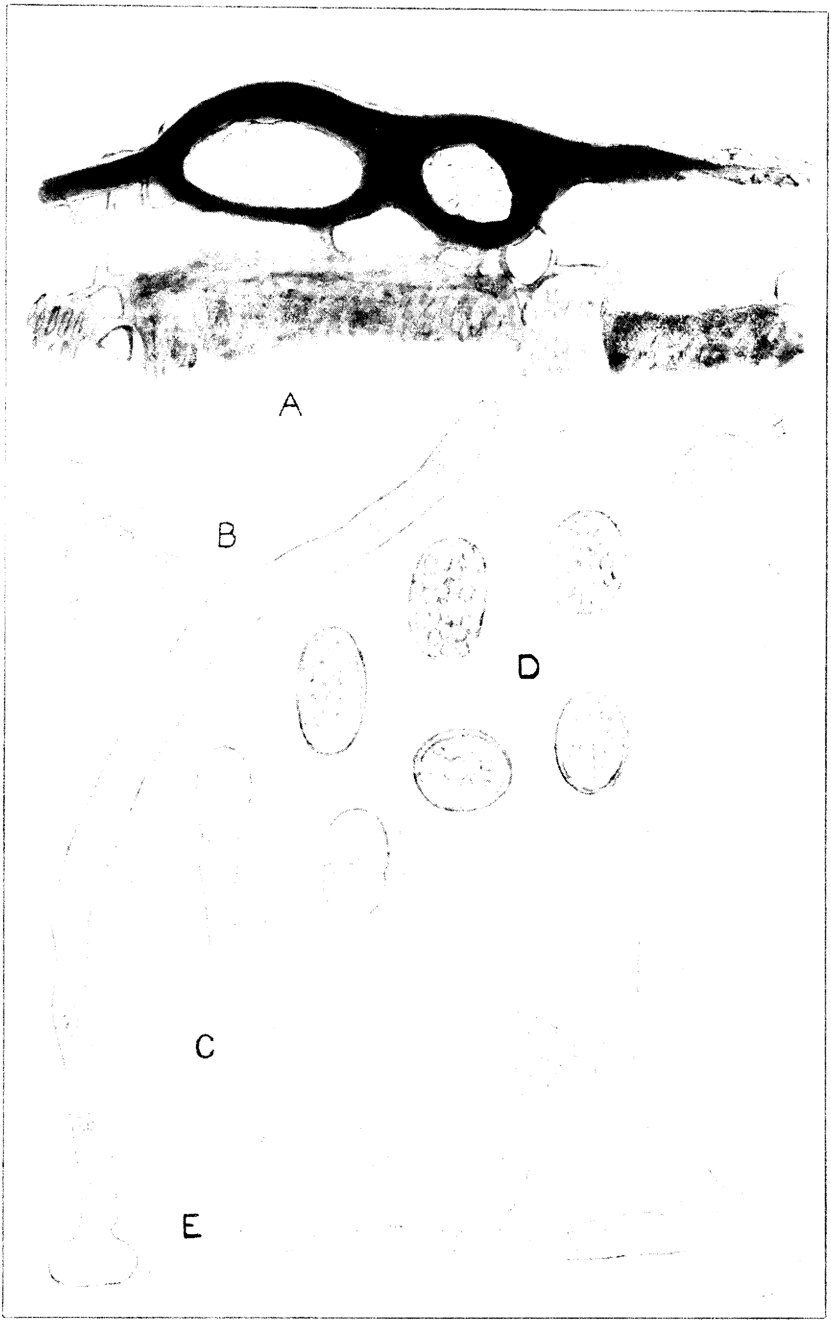


FIG. 1.—BUNCH OF GREEN CHINESE BANANAS, SHOWING FRECKLE DISEASE.



BANANA FRECKLE (PHOMA MUSÆ N. SP.

A, Camera lucida drawing showing pycnidia and spermagonia on green fruit (× 150); B, spermatia; C, conidiophore and forming conidium; D, conidia with gelatinous envelope and appendage; E, germination of pycnospores (B, C, D, and E, × 1000).

bases his opinion that this is a new disease in Hawaii upon the following observations, as well as upon the testimony of the majority of the growers: The disease has been localized for two or more years in Kalihi; if at any time within recent years such an epidemic as is now present in Kalihi had occurred there, the growers would have retained some recollection of it; though one year ago the disease could scarcely be found in Manoa, where the conditions are similar to those in Kalihi, it is now prevalent there to an alarming extent; the plantations of Mokuleia have been free from the disease until the past few months. On the other hand there is a possibility that this disease has previously destroyed large areas of Chinese bananas in other sections of the islands. The writer is informed that this variety of bananas was once extensively planted near Hilo, but that a disease which may have been the same as the freckle disease was responsible for the abandonment of the industry there.

Since this disease appears to be new to pathologists, no record of a disease which can be determined as identical having been found, such notes as may prove valuable to a prompt diagnosis are given here in order that the spread of the disease to other countries growing Chinese or dwarf bananas may be checked if not prevented. The following description of the disease and the organism found associated with it is in the nature of a preliminary report and further investigation is required.

Defoliation, weakened plants, ultimately becoming worthless, and undersized fruit as well as undeveloped bunches which have to be cut prematurely are all results of this disease. Although in many cases the quality of the fruit seems to be unimpaired by the surface blemish, fruit bunches at all badly affected are rendered so unsightly that they are totally unsuited for export and have to be disposed of with difficulty on the local market at about one-fourth the usual price.

Under normal conditions about 230,000 bunches of bananas per year are exported to the mainland from Hawaii, almost entirely from the island of Oahu. The total annual production of this fruit in the islands is not far from 300,000 bunches. The Chinese banana, predominantly the export variety, appears to be the only sort attacked by freckle. If other plantations suffer as severely as those of Kalihi, it would seem only a matter of two or three years before no more bananas of quality suitable for export are produced. The disease, probably encouraged in the valleys by the frequent trade-wind showers, may not prove so disastrous in the outlying plantations.

Investigation has shown that the minute, black, pustule-like spots on the leaves and green fruits are subepidermal pycnidial fruiting bodies (Pl. IX, A) containing spores (Pl. IX, B, C, D, E) closely resembling the pycnospores of *Guignardia vaccinii* and *G. bidwellii.*

The fruit spots are at first minute (about 1 millimeter in diameter), grayish, rounded, and with indefinite border, suggesting small areas of extravasated sap in the surface tissues. With a hand lens the center of the spot is seen to be reddish brown in color. The spots become more definitely round and slightly erumpent as the banana develops and are jet black in color when the fruit is "full" (ready to cut). Though the pycnidia themselves are seldom confluent, they are usually present in great numbers and so closely disposed that large areas of the leaves and green fruit are blackened. In moist weather the mature pycnidia exude white gelatinous tendrils of spores. The pycnidia are not beaked, and the ostiole, though frequently plainly to be seen, is not at all conspicuous.

The pycnidia of the fungus are to be found on the upper surface of the leaves, apparently as stomatal infections and similarly on the more exposed surfaces of the fruits. On the latter they are first observed as minute grayish "freckles" on the upper surface of the upper hands of the bunch near the base of the individual fruit. In other words, the infections occur on those parts most frequently moistened by light showers and apparently where spores lodge when carried from the leaves by rain. In diameter the pycnidia are from 60 to 150μ, and most commonly about 135μ (Pl. IX, A). Spermagonia (Pl. IX, A) containing spermatia (Pl. IX, B) resembling those illustrated by Reddick[1] are also present, though less frequently than the pycnidia. The spermatia measure 2 to 7 by 1 to 2μ, or roughly ten times the figures recorded by Reddick (apparently a typographical error in placing the decimal point).

The pycnospores or conidia are ovoid, rather hyaline, inclosed in a gelatinous envelope with one appendage (Pl. IX, D), and densely packed with globular bodies (oil droplets?). The spores when first issuing from the pycnidium are commonly irregularly ovoid and angular from mutual pressure and contact. As above noted, they resemble the pycnospores of *Guignardia* spp. Disregarding the appendage and gelatinous envelope, which are not constantly present, the spores measure 11 to 17.5 by 5 to 12.2μ. Those of *G. vaccinii* are given as 10.5 to 13.5 by 5 to 6μ by Shear.[2] Those of *G. bidwellii* measure 8.5 to 11.5 by 6.5 to 8.5μ, according to Reddick.

Although the pycnospores germinate readily in sterile distilled water in one to two days (Pl. IX, E), attempts to grow the fungus on media suitable to the culture of other fungi or on several special media concocted for the purpose have thus far failed. In most cases *Glœosporium* spp. quickly develop and monopolize the medium. This failure in culturing, accompanied by the constant development of Glœosporium in the early trials, led to the impression that a species of the latter genus was responsible for the disease. Several bacteria have also been isolated from stomatal lesions, but their relation to the freckle disease remains to be determined.

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[1] Reddick, D. The black rot disease of grapes. New York Cornell Sta. Bul. 293 (1911), pp. 289-364.

[2] Shear, C. L. Cranberry diseases. U. S. Dept. Agr., Bur. Plant Indus. Bul. 110 (1907), p. 15.

Since the pycnidial fungus which appears to be constantly associated with the disease has not yet been produced in culture and as nothing is known of its perfect stage, a satisfactory description can not be furnished. Until the perfect stage shall be found, the name *Phoma musae* is suggested for the fungus.

Phoma musae n. sp. Pycnidia globose, subcoriaceous, black, immersed to slightly erumpent, separate, ostiolate, foliicolous, and fructicolous. Conidia ovoid, hyaline, closely packed with oil droplets(?), capsulated with gelatinous envelope with one appendage, one-celled, in germination sometimes apparently becoming one-septate; measuring 11 to 17.5 by 5 to 12.2 μ. Spermagonia similar to pycnidia but slightly smaller; spermatia hyaline, appearing dumb-bell shaped, 2 to 7 by 1 to 2 μ.

CONTROL.

Only those sanitary practices applicable in all plant diseases of a similar nature can be safely recommended as control measures until further investigation shall point the way. No method of control has yet shown any promise. It is believed that cleaning up and burning diseased leaves and débris, replanting suckers from healthy plants, and spraying the leaves periodically with Bordeaux mixture and thus keeping down the leaf infection until the bunch appears and matures, will tend to reduce fruit infection. The disease appears to progress slowly and would possibly be of little consequence on the fruit if the latter were not infected by the spores carried by water draining from the blackened leaves. It may be found advisable to spray the fruit with ammoniacal copper carbonate, which would be less likely to leave an objectionable stain than would the Bordeaux mixture. As banana plantations are laid out without roads and on steep hillsides in many cases, they present considerable difficulty in the practicable application of spray mixtures. Some of the plantations on level ground, if properly laid out, would offer no more mechanical difficulty in spraying, should this method of control be found desirable, than an apple orchard or an orange grove.

A fungus similar to *Phoma musae* has been found associated with a black spot disease of algaroba (*Prosopis chilensis*) pods, but this disease does not appear to be very prevalent. Other hosts of the banana fungus or similar ones are not known to occur in Hawaii. *Guignardia bidwellii*, the cause of black rot of grapes, has not been detected.

This freckle disease of the Chinese banana is a serious menace to the industry, and if not a new disease in Hawaii, it is certainly new in epidemic form. Those interested in banana growing are urged to realize the threatening aspects of this disease and to attempt control along the lines suggested and others which appear feasible, as increasing the vigor of the plants through fertilization, rotation, etc.

IRISH POTATO DISEASES.

Late blight (*Phytophthora infestans*) and wilt (*Fusarium oxysporum*) continue to be the most serious fungus diseases of the Irish potato in Hawaii. The potato tuber moth (*Phthorimaea operculella*) and the mite disease (infestation with an undetermined species of mite allied to red spider), together with the early blight disease (*Alternaria solani*), were especially destructive during the protracted drought of the summer of 1917 in the Kula and Makawao sections of Maui and in the Hamakua section of Hawaii. The early blight disease was then for the first time observed to be an important factor in Hawaiian potato culture.

MITE DISEASE.

The mite disease, an apparently new trouble of the Irish potato mentioned in the 1917 report of this division, is found to be much more widely prevalent and destructive than was at first believed. It has been observed thus far in the following localities, which furnishes a basis for the assumption that it occurs practically all over the islands at the lower elevations: Mokuleia, Castner, and Honolulu, Oahu; Kula and Makawao, Maui; Hamakua, Hawaii; and Hanalei, Kauai.

Experiment has shown that where the conditions are favorable for potato culture the mites may be kept off the plants by dusting with dry sulphur or spraying with lime-sulphur spray. The trouble may be avoided to a great extent by planting sufficiently early for the crop to mature before the dry season sets in. In any case it should be borne in mind that the Irish potato is a cool-weather crop and that during the dry season the climate of Honolulu and other localities near sea level is not well adapted to its culture. Apparently the mite disease will not prove a serious menace to the potato industry at elevations of 1,500 to 4,000 feet except in abnormally dry years. In this contingency, spraying and dusting with sulphur offers a practical means of control.

LATE BLIGHT.

During the year considerable additional evidence was accumulated showing the effectiveness of Bordeaux mixture as a preventive of late blight. Increased yields of sprayed over unsprayed plats of 50 to 200 per cent were obtained. Much of the evidence was of a nature to appeal to the eye, and accurate figures were secured in few

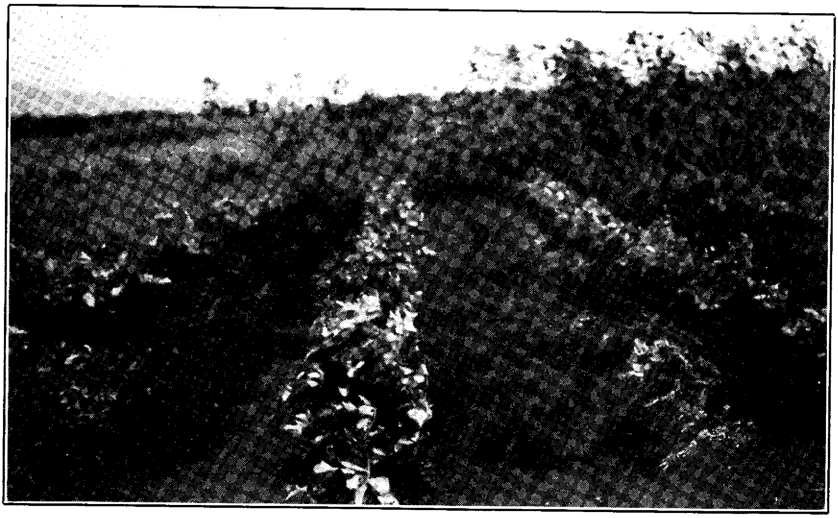

FIG. 1.—ROWS OF HAMAKUA HYBRID POTATOES RESISTANT TO LATE BLIGHT WITH BADLY BLIGHTED ROWS OF EARLY ROSE VARIETY BETWEEN.

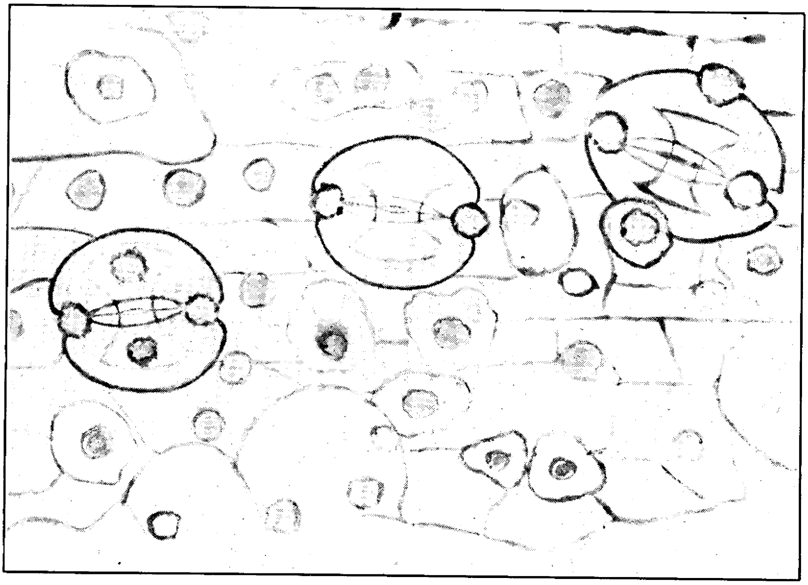

FIG. 2.—STOMATA OF PINEAPPLE LEAVES.

Camera lucida drawing (× 1000).

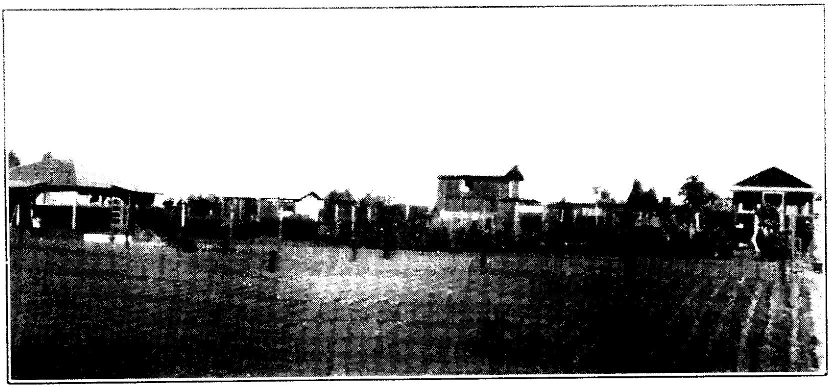

Fig. 1. Demonstration Substation, Haiku, Maui.

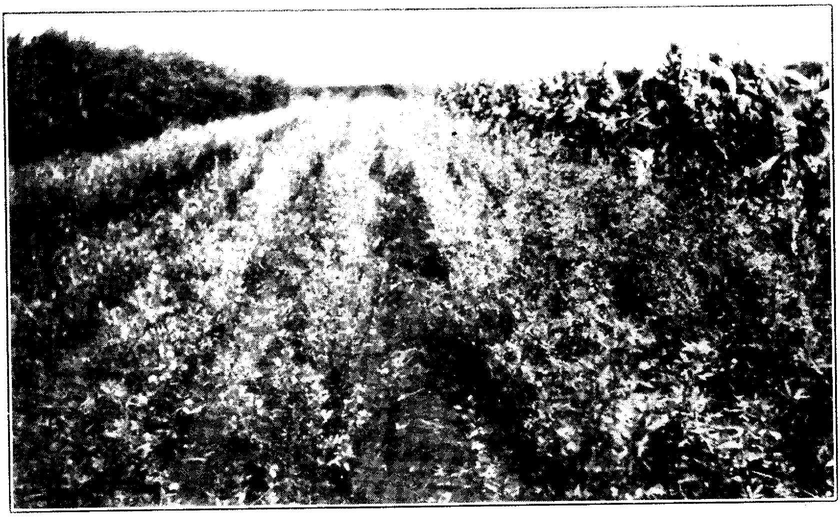

Fig. 2.—Fertilizer Experiments with Alfalfa, Castner Substation. Fertilizer Drilled in Rows in Center, Applied as Spray on Right.

cases. Owing to the conflicting results where badly wilt-infected stands were sprayed, some growers remain to be convinced of the efficacy of the treatment. No amount of spraying in stands badly infected with wilt (*Fusarium oxysporum*) and rosette (*Rhizoctonia* sp.) will serve to bring forth a good yield, spraying in such stands serving only to furnish a basis for criticism of spraying in general. Only in stands of potatoes worth spraying to prevent the late blight can the effectiveness of Bordeaux mixture as a preventive spray be properly appreciated. In view of the conflicting evidence of the value of Bordeaux, efforts to improve the potato industry may well center about the practice of seed selection and crop rotation for the improvement of the general vigor of the plants and the elimination of Fusarium wilt and rosette disease.

As an example of the value of Bordeaux spraying may be cited the 7-acre crop of potatoes grown this spring at Kemoo farm near Castner, Oahu. This crop was sprayed thoroughly, and although it was attacked by the late blight, this disease was held in check by prompt and effective treatment at critical times. It is estimated that this crop will yield about 85 bags per acre of as fine potatoes as can be raised anywhere.

A potato variety resistant to late blight.—A potato variety originated by Miss K. Yamato, of Honokaa, Hawaii, is reported to be much more successfully grown in that locality than any other variety tried. This type of potato, which has been called the Hamakua Hybrid from the locality where it was originated, is a composite of two sorts. One parent of both sorts appears to have been the local variety known as the Portuguese Purple, which was brought to the islands from Madeira by Portuguese emigrants. One sort appears to be the result of a natural cross between the Portuguese Purple and the Burbank type, the other a cross of the Portuguese Purple with the Early Rose variety. In conversation with the originator, it appeared that exact records were not kept, though the above is essentially her recollection of the parentage of the two strains.

The Portuguese Purple variety, though not a desirable culinary type, possesses considerable blight resistance. The Hamakua Hybrid of the Burbank type is of much better quality, though lacking mealiness in cooking and having deep eyes which cause loss in peeling. Altogether it appears to be more desirable than the other strain, or Early Rose type.

The evidence in hand indicates that the Hamakua Hybrid has a very promising degree of resistance to the Phytophthora leaf blight in these islands.[1] Experiments thus far have given conflicting results, but the writer is of the opinion that failure on the part of growers to recognize the several potato diseases, as Fusarium wilt, rosette, early blight, and mite infestation, is partly responsible for the unfavorable reports on this variety. Whether the tubers of the Hamakua variety possess resistance to the late blight rot is not known, since this phase of late blight injury is comparatively rare in Hawaii, possibly owing to its porous, well-drained soils.

At the Glenwood substation[1] two variety tests by different investigators have shown the practical value of the Hamakua Hybrid in that district, where it was successfully grown in one patch of 4 acres with a reported yield of 401 bags. The grower was so impressed with this result that he proposes to plant about 40 acres to this variety. As the Glenwood section has an annual rainfall of some 250 inches, with few days in the year without some rain, it has previously been highly discouraging to grow potatoes there, since, on account of the frequent showers and deluging rains, spraying was found to be impracticable.

The Hamakua Hybrid and the Portuguese Purple varieties have also been strikingly resistant to late blight in the cooperative tests in the gardens at Schofield Barracks, where, in order further to test the resistance of the Hamakua Hybrid, this variety was grown in comparison with the Early Rose variety. Owing to the poor soil and the lack of irrigation water, no variety yields normally there, but the differences in yield in this test are rather striking. Both varieties grew well in the first month, but at the end of 60 days the tops of the Early Rose had been destroyed by the late blight (Pl. X, fig. 1), and the 96 hills yielded only 7½ pounds of small tubers. The Hamakua Hybrid remained almost without a trace of blight through another two months of weather favorable to blight. The dry season commencing at the beginning of the fourth month, 20 hills were dug at this time, with a yield of 9½ pounds of fair-sized tubers. The rest were allowed to grow another month, but the dry soil seemed to prevent any additional growth, 58 hills yielding only 27 pounds. The average yield per hill of the Early Rose variety was 0.078 pound and for the Hamakua Hybrid 0.468 pound.

No doubt the quality of this resistant type can be greatly improved by selection and by further crosses with desirable market types. Since the Phytophthora blight is the most serious of potato diseases the world over, the practical value of a desirable market potato resistant to this disease has long been evident, and the development of such a type is the aim of investigators. Numerous varieties offering promise have been brought out in Europe, some showing considerable resistance, but they are not of the quality to win recognition on the American markets.

COFFEE DISEASES.

In Kona, Hawaii, where most of the Hawaiian coffee is grown, this crop is often considerably damaged by the sooty mold, or "fumagine," which lives saprophytically on the honeydew from certain scale insects. Whether the black fungus involved belongs to the genus Capnodium or to Meliola has not been determined. In Kona the sooty mold follows commonly the green scale (*Coccus viridis*), which is present most abundantly in dry seasons and where the coffee is grown in the open. The solution of the difficulty would appear to be in the use of proper shade trees, since the green scale is not so prevalent in the shade. Coffee does best in shade such as is afforded by silk oak (*Grevillea robusta*), the monkey pod (*Pithecolobium saman*), or other trees which do not in themselves harbor the scale, the honeydew from which would fall on the coffee foliage and nourish the molds.

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[1] Hawaii Sta. Rpt. 1917, pp. 46–48.

There is a die-back disease of coffee, as well as other troubles, in Kona, but there has been no opportunity to investigate them more than casually.

MISCELLANEOUS INSECT AND FUNGUS DISEASES.

Diseases not hitherto reported in Hawaii.—So far as is indicated by the available records, the following diseases observed during the year have not been previously reported in Hawaii:

Algaroba (*Prosopis chilensis*). Black spot of pods. Pycnidial fungus similar to organism *Phoma musae* n. sp. associated with black spot of Chinese bananas. Pycnospores appendaged, measuring 10.9 by 7.3µ. Pycnida 145 to 165µ, ostiole readily seen, 15µ in diameter.

Bean (*Phaseolus* sp.). Rust (*Uromyces appendiculatus*), leaf and pod spot (*Isariopsis griseola*).

Brassica (*Sinapis cernua*), "kai choy." White rust (*Albugo candida*).

Cactus, prickly pear (*Opuntia* sp.). Blight (*Diplodia opuntiae?*).

Carrot (*Daucus carota*). Root knot due to nematodes.

Cotton (*Gossypium* sp.) Anthracnose (*Glomerella gossypii*).

Eggplant (*Solanum melongena*). Leaf spot (*Phyllosticta hortorum*), root knot due to nematodes.

Litchi (*Litchi chinensis*). Leaf blight due to ascigerous fungus of Glomerella type.

Peanut (*Arachis hypogaea*). Wilt (*Sclerotium rolfsii*), leaf spot (*Septogloeum arachidis?*).

Rice (*Oryza sativa*). Blast (*Piricularia grisea*), stem and root disease associated with *Pythium* sp. (?).

Roselle (*Hibiscus sabdariffa*). Root disease associated with *Fusarium radicicola*.

Sorghum (*Sorghum* sp.). Smut (*Ustilago reiliana?*).

Tobacco (*Nicotiana tabacum*). Mosaic disease, root knot due to nematodes, vascular disease, Granville wilt (?).

Tomato (*Lycopersicum esculentum*). Mite disease (mite apparently the same as potato mite described on p. 40).

Potato (*Solanum tuberosum*). Early blight (*Alternaria solani*), common scab (*Actinomyces chromogenus*), tuber rot (*Fusarium coeruleum*), and tuber galls due to nematodes.

Turnip (*Brassica campestris*). Root scab (*Rhizoctonia* sp.), white rust (*Albugo candida*).

Miscellaneous fungus and insect pests.—Among other diseases and pests observed during the year were the following:

Avocado (*Persea gratissima*). Blight (*Glomerella cingulata*).

Banana (*Musa cavendishii*). Red spider.

Bean (*Phaseolus* sp.). Anthracnose (*Glomerella* (*Gloeosporium*) *lindemuthiana*).

Cabbage (*Brassica oleracea*). Webworm (*Hellula undalis*), green cabbage worm (*Pontia rapae*), bacterial soft rot.

Coffee (*Coffea* sp.). Sooty leaf mold (*Capnodium* sp.?).

Corn (*Zea mays*). Leaf hopper (*Peregrinus maidis*); mottling disease similar to yellow stripe disease of corn, cause undetermined.

Guava (*Psidium guajava*). Russeting due to red spider.

Litchi (*Litchi chinensis*). Erinose (*Eriophyes* sp.).

Mango (*Mangifera* sp.). Blight, (*Glomerella cingulata*).

Monterey cypress (*Cupressus macrocarpa*). Roaches.

Onion (*Allium cepa*). Thrips.

Potato (*Solanum tuberosum*). Tuber moth (*Phthorimaea operculella*), wilt (*Fusarium oxysporum*), tuber rot (*Fusarium oxysporum* and F. *radicicola*), and rosette (*Rhizoctonia* sp.).

Pineapple (*Bromelia* sp.). Bud rot (cause?), wilts of several types apparently not caused by parasitic organisms but suggesting malnutrition.

Taro (*Colocasia* sp.). Root rots of several forms, a species of Pythium (?) associated with most common type.

Tomato (*Lycopersicum esculentum*). Blight (*Phytophthora infestans*).

STOMATA IN THE PINEAPPLE LEAF.

In a bulletin of this station[1] Wilcox and Kelly report that they were unable to find stomata in pineapple leaves, and they conclude that true stomata are not present. To quote from these writers:

> One of the peculiar features of the pineapple leaf is the apparent absence of stomata. Hundreds of sections were made from pineapple leaves and examined under the miscroscope, and portions of the epidermis of the upper and under sides of the leaves were carefully examined without finding any true

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[1] Hawaii Sta. Bul. 28 (1912), p. 9.

stomata. There are in some parts of the leaves pits in the epidermis in which much branched scale-like trichomes are attached. These structures are particularly numerous on the underside of the leaf near the base. The trichomes in question are supposed to be connected with the absorption of water.

In view of the prompt reaction of yellowed pineapple plants growing on manganese soil to a spray of iron sulphate,[1] examination of the surface and of cross sections of pineapple leaves was made several times, and in each case true stomata were found (Pl. X, fig. 2). They are located in the bottom of the furrows on the underside of the leaves and are present at an estimated average rate of 120 per square millimeter. They are not strikingly different from the stomata of other plants. None were found on the upper surfaces.

The guard cells of the pineapple stomata are in slight depressions below the surface of the bottom of the furrow. In sections mounted in water for examination with the microscope, they are obscured by an abundance of much-branched, scale-like trichomes and free scales from the latter. The included air bubbles in the scales render the stomata difficult to see. In surface sections cut from the under surface of a pineapple leaf which has been wiped with alcohol the stomata may be readily identified, and they are not especially difficult to find in cross sections of similar material.

REPORT OF THE AGRONOMY DIVISION.

By C. A. SAHR.

Problems affecting food production and conservation have constituted the chief work of this division, the lines of investigation having been gradually changed from the original projects to those more directly applicable to emergency food-crop production.

POTATOES.

Because of the very unfavorable soil conditions at the central station at Honolulu, all the work with Irish potatoes done by this division was carried out at the forage-crop station near Castner. In a test to determine the blight resistance of various standard varieties and the new Hamakua Hybrid potato, a planting was made of 16 hills each of Early Rose, Burbank, Hamakua Hybrid (Terry), Hamakua Hybrid (Haiku), and Portuguese Purple under date of February 5, 1918. Examination of these stands made April 1 disclosed the presence of late blight on the entire stands of the Burbank and Early Rose and blackened surfaces on the foliage on two plants of the Hamakua Hybrid (Haiku). The last of the Burbank stand succumbed to blight on April 18, followed by the Early Rose on April

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[1] Hawaii Sta. Press Bul. 51 (1916).

22. The two plants of the Hamakua Hybrid (Haiku) noted as bearing blackened surfaces on their foliage April 1 were the first of the blight-resistant varieties to succumb, they being recorded as dead on May 1. The entire stands of Hamakua Hybrid (Terry), Hamakua Hybrid (Haiku), and Portuguese Purple were found to be quite dead on May 10.

RICE.

The work with rice was continued at Waiau, Oahu. Due to the rice-blast disease and an as yet unidentified root disease attacking the rice, the data obtained from the aeration, fertilizer, and green manuring tests for the 1917 fall crop are unreliable. In the rotation test with rice following taro, data from two Japanese rices, Kukiruki and Okabu, were obtained. With the Kukiruki variety the increase favoring rotation amounted to 872 pounds, or 17 per cent, with the Okabu 944 pounds, or 17.7 per cent.

CORN.

Due to the many previous failures with corn caused by persistent attacks of the corn leaf hopper (*Peregrinus maidis*), the work on corn during the early portion of the past year consisted chiefly of testing numerous varieties for leaf-hopper resistance. Seed of native Guam corn received from Mr. A. C. Hartenbower, at that time agronomist in charge of the Guam Experiment Station, was planted in June, 1917, Leaming Yellow being used as a basis of comparison. While the stand of native Guam obtained was very poor, several examinations disclosed the fact that the plants of this variety appeared to be exceedingly free from leaf-hopper attacks, while the entire stand of Leaming Yellow was heavily infested. Following this discovery, the station received a donation of 15 pounds of Guam corn from E. W. H. Broadbent, of Lihue, Kauai, with which extensive planting was made August 3, 1917, together with 10 varieties received from the Bureau of Plant Industry, United States Department of Agriculture. The results of this variety test are given in the following table:

Variety tests of corn.

Variety.	Number.	Shelled corn per acre.	Variety.	Number.	Shelled corn per acre.
		Bushels.			*Bushels.*
Boone County White	1106	0	Funk's Ninety-Day	1112	13.7
Commercial White	1107	0	U. S. Select	1113	16.2
Virginia Horse Tooth	1108	0	Yellow Leaming	1114	11.8
Hickory King	1109	0	Northwestern Dent	1115	10.9
North Dakota Flint	1110	0	Native Guam		46.7
Creole	1111	39.2			

A second variety of corn (Cuban Red), a reddish-yellow sort introduced by the College of Hawaii, was likewise tested by this division at the forage crop station near Castner. While this variety also showed remarkable resistance to leaf-hopper attack, its drought-resistant qualities were found to be somewhat poor.

LEGUMES.

Two trial plantings of six varieties of button clover were made during the year. The first planting was made at the forage-crop station at Castner and the later planting in field N of the station grounds in October. In both plantings only two of the six varieties, *Medicago scutellata* (S. P. I. No. 26077) and *M. orbicularis* (S. P. I. No. 10725), made any promising growth. In both instances *M. scutellata*, while attaining considerable size, was killed off by attacks of aphids. The first growth obtained with *M. orbicularis* in the field N planting, as long as it was erect, was exceedingly promising, but as the plants became procumbent, or trailing, due to increased growth, damage caused by the wind was very evident, preventing setting of the blooms. This was further evidenced by the growth assumed by *M. orbicularis* when sown both in open places and in Bermuda-grass sod at Castner, the plants flourishing best when their trailing stems were supported and partially shaded by the grass. Other plantings of particular interest are of annual types of white sweet clover (*Melilotus alba annua*), seed of No. 1155 having been received from the Bureau of Plant Industry, United States Department of Agriculture, under F. C. I. No. 10001, and of No. 1209 from Prof. H. D. Hughes, Iowa State College. Both lots were planted at Castner, No. 1155, sown in January, coming into full bloom in early June; No. 1209, sown in April, showing favorable progress at the end of the fiscal year.

GRASSES.

Cuttings of new grasses received from the Office of Forage Crop Investigations April 24 include blue couch grass (F. C. I. No. 2378), Cayenne grass (F. C. I. No. 38746), Palm Beach grass (F. C. I. No. 02329), *Zoysia* spp. (F. C. I. No. 02839), *Capriola dactylon* (S. P. I. No. 31596), *Saccharum biflorus* (S. P. I. No. 42551), and *Andropogon emersus* (S. P. I. No. 41884). These grasses were set out in the grass garden at Castner April 30, 1918.

A sample of grass seed received under the name Prolifikeeno from John McCoy, of Fabens, Tex., was planted in two plats in field N October 2, 1917. Both plats came into full bloom in 55 days and were cut December 1, 60 days after planting, yielding at the rate of 15 and 15.7 tons green forage per acre. Its close resemblance to Johnson grass in the appearance of underground suckers shortly after cutting made it seem desirable to eradicate the stand to prevent any possibility of its spreading as a pest.

EDIBLE CANNA.

Due to the popular demand early in the year for tubers of the edible canna (*Canna edulis*) for home gardens, various plantings of this important food crop were made from time to time to serve as sources of planting material. As the plant failed to make a luxuriant growth in some of the home gardens, chiefly as a result of poor soil conditions, a fertilizer and manuring test was inaugurated. The plats, consisting of 10 hills each 3 feet apart each way, were planted September 28, 1917, and harvested June 12, 1918. The results of this experiment are given in the following table:

Fertilizer test with edible canna.

Row No.	Fertilizer applied per acre.	Yield from 10 hills.			Estimated acre yields.	
		Number of tubers.	Weight.			
			Tubers.	Tops.	Tubers.	Tops.
			Pounds.	*Pounds.*	*Tons.*	*Tons.*
1	Ammonium sulphate, 250 pounds; nitrate of soda, 150 pounds	283	170	151.5	41.14	36.66
2	Ammonium sulphate, 250 pounds: superphosphate, 250 pounds; sulphate of potash, 250 pounds	248	177	155.5	42.83	37.63
3	Check	201	117.5	79	28.43	19.11
4	Barnyard manure, 20 tons	271	169	129.5	40.9	31.34
5	Ammonium sulphate, 200 pounds; superphosphate, 100 pounds; sulphate of potash, 100 pounds	167	93	84	22.57	20.32

In conjunction with the fertilizer test with edible canna, a test was made involving two different types of tubers (cylindrical to tapering and spherical to oval), with the object of obtaining definite data on the yields from the two tuber types used as sets. The results of this test, which included 25 hills of each type, are summarized in the following table:

Comparative yields from cylindrical and spherical tubers of edible canna.

Row No.	Type of tuber.	Weight of washed roots.	Estimated acre yields.
		Pounds.	*Tons.*
1	Cylindrical	382.5	37.13
2	Spherical	335.5	32.02
	Difference	47	5.11

CASSAVA.

The various stands of White Trinidad, White Waialua, and the red, bitter cassava have been maintained in order to keep up with the demand for cuttings. Cuttings of five varieties of cassava cultivated in various provinces of the Philippine Islands and received from the

Bureau of Agriculture, Manila, P. I., in early June, are already established on the station grounds. It may be of interest to note that as cassava has become established in a great many home gardens throughout the Territory, the publication in the local press of various methods of preparation of dried cassava roots and the culinary uses of these as tested out in the household of the writer, has proved of great benefit to the public.

SWEET POTATOES.

Preliminary work with sweet potatoes was begun by this division during April, 1917, the object in view being to supply propagating material for distribution, but the demand for cuttings became so great as to make it seem advisable to broaden materially this field of work. Through the efforts of H. L. Chung, of the division of agronomy, in selection and breeding from standard types and varieties, this division is now able to distribute cuttings of varieties which are well recognized for their good producing qualities.

TIMELY ARTICLES FOR THE LOCAL PRESS.

In order to reach the people of the islands promptly with practical information along food and feed production lines, the following articles were prepared for the local press and printed during the year: Crop Protection and Fumigation, Tepary Beans, Sweet Potatoes, Rape for Hogs and Poultry, Pork Production, Aphis Control, Guam Corn, Cassava Flour, Guam Corn *v.* Seed Corn Shortage, Buckwheat, Potato Spraying by Army Gardeners, Household Uses for Cassava, Doubling Corn, Broom Corn, and Napier Grass.

FORAGE CROP AND FOOD CROP PROBLEMS AT CASTNER, OAHU.

The most important work of the year consisted in keeping an accurate record of the yields of the forage crops involved in the soil-heating and manuring test begun in 1917.[1] The first year's results with the most promising crops are given in the following table:

Comparative yields of forage crops on manganese soil given heat treatment and stable manure.

Crop.	Division A, no treatment.	Division B, ditched soil heated.	Division C, level soil burned over.	Division D, stable manure, 33 tons per acre.
Grasses:	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Rhodes	16.9	32.9	25.5	40.4
Teff	....	3.7	3	7
Sudan	.7	6.1	5.5	13.6
Wilder	3.3	7.7	8.3	20.4
Tunis	4.1	11.5	7.1	42.9
Sorghums:				
Adyiba	5.2	13.4	14.1	53.2
Sugar Drip	14.4	13.6	22.8	40.7
Legumes:				
Peruvian alfalfa	3.5	11.5	10.2	16.4
White sweet clover	1.6	7.2	7.3	18.1
Edible canna:				
Tubers	5.5	12.68	11.96	21.43
Tops	5.55	12.15	17.15	28

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[1] Hawaii Sta. Rpt. 1917, pp. 53, 54.

A further study of the effect of iron compound spray upon the yields of Peruvian alfalfa and Japanese cane is being made. In the test of applications of copperas to the alfalfa, a 0.25 per cent solution was used in each instance, first one week after each cutting and again two weeks later, after which the stands were allowed to come into full bloom before cutting. The Japanese cane was sprayed every two weeks for a period of six months, beginning in April, 1917. Following the spraying periods, the stand was laid by until harvested on April 30, 1918. The results of this work are summarized in the following table:

Effect of copperas solution upon alfalfa and Japanese cane.

Plat.	Crop.	Treatment.	Yield on—					
			July 17, 1917.	Oct. 29, 1917.	Feb. 14, 1918.	Apr. 18, 1918.	May 16, 1918.	June 26, 1918.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
I-a	Peruvian alfalfa	Sprayed	554	1,148	1,013	1,013	1,913	1,419
I-b	do	Unsprayed	459	959	593	608	1,481	432
	Increase due to spraying—per cent.		20.7	18.6	69.1	66.6	29.1	228.4
II-a	Peruvian alfalfa	Sprayed	931	1,305	769	1,485	3,434	1,285
II-b	do	Unsprayed	809	1,244	688	1,133	2,570	1,121
	Increase due to spraying—per cent.		15	4.9	11.8	31	33.6	14.6
III-a	Japanese cane	Sprayed				7,610		
III-b	do	Unsprayed				5,291		
	Increase due to spraying—per cent.					43.5		

Due to the marked increase in the yields of alfalfa obtained as a result of spraying with copperas solutions, spraying and drilling tests were begun with other fertilizers and fertilizer solutions used in conjunction with the iron sprays (Pl. XI, fig. 2). The same alfalfa plats were used in this test as with the iron sprays alone. The check row for the iron spray of each plat was likewise check row in this test. The results of this test are given in the following table:

Effect of spraying alfalfa with iron and fertilizer compounds.

Kind, amount per acre, and method of treatment on Sept. 28, 1917.	Yield on—			Kind, amount per acre, and method of treatment On Apr. 15, 1918.	Yield on—	
	Sept. 29, 1917.	Feb. 14, 1918.	Apr. 8, 1918.		May 16, 1918.	June 26, 1918.
Lime, 118 pounds:	*Pounds.*	*Pounds.*	*Pounds.*	Lime, 1,000 pounds:	*Pounds.*	*Pounds.*
Drilled	1,013	243	296	Drilled	523	555
Sprayed (milk of lime)	1,467	1,518	2,824	Sprayed (milk of lime)	3,785	1,775
Sulphate of potash, 118 pounds:				Sulphate of potash, 250 pounds:		
Drilled	945	541	594	Drilled	6,296	432
Sprayed	1,214	971	1,254	Sprayed	2,803	1,387
Check:				Check:		
Drilled rows	1,959	593	608	Drilled rows	1,481	432
Sprayed rows	1,244	688	1,133	Sprayed rows	2,570	1,121
Copperas, 5 pounds:				Copperas, 5 pounds:		
Drilled	1,148	1,013	1,013	Drilled	1,913	1,419
Sprayed	1,305	769	1,485	Sprayed	3,434	1,285
Superphosphate, 118 pounds:				Superphosphate, 250 pounds:		
Drilled	2,540	3,040	2,959	Drilled	2,438	5,154
Sprayed	2,830	2,226	3,289	Sprayed	7,593	3,084

Other work of importance was the inauguration of a fertilizer and manuring experiment with cassava and edible canna. In conjunction with this test a second fertilizer experiment without the use of manure was also inaugurated before the dry season set in.

REPORT OF THE GLENWOOD SUBSTATION.

By R. A. Goff.

The primary object of the work carried on at the Glenwood substation during the past year was to demonstrate that desirable and economic food and forage crops can be grown in the Glenwood district and to put these results directly before farmers and agricultural producers. The various nationalities represented among the growers make it difficult to distribute information through bulletins and circulars. To overcome this difficulty, two days of each week were spent in actual demonstration work among the farmers. The result has been to bring home to the local farmers the possibility of relying less on imported feeds and food crops and to depend to a greater extent on home-grown feed for stock.

DAIRY.

Glenwood has been for some time a dairy district from which considerable quantities of butter have been sent to the local markets. However, a serious difficulty in the way of successful and profitable dairy farming has been the dependence of the local dairymen on imported milled feeds to supplement the native grasses which can easily be grown in the district. Dairying is nearly always more profitable where the products grown on the farm are marketed in the form of milk or butter, but when it is necessary to import all or nearly all of the concentrates, a large share of the profit that should go to the dairyman is paid to the transportation companies and grain farmers who have produced the milled feeds. To overcome this difficulty, experiments with 20 or more forage crops have been carried on, two or three of these having given very promising results. It has been demonstrated on small plats that two crops of corn a year can be successfully grown, and when a practical method of drying the corn has been worked out, a valuable concentrate will be available for local dairymen. The small grains head out well but do not fill, and work is being done in saving the occasional grains that mature in an effort to obtain seed that will be acclimated to the region.

ALFALFA.

Alfalfa is not usually considered a concentrate, but when made into meal it is practically the equal of imported wheat bran. Work with alfalfa was carried on from the point to which it had been developed in previous years at this station. It has been demonstrated that alfalfa can be grown in this region if the cutworm and snail can be overcome, and a demonstration plat has been planted with seedlings transplanted from small flats which were protected from the rains and treated with poison mixtures applied when the plants were attacked by pests. Within a year from planting this plat had produced at the rate of over 30 tons of green feed to the acre, in spite of the fact that the distance between rows and between plants in the row was greater than would be used in actual field operations. For some time during the past year seed was planted in the flats because it was not believed possible to plant directly in the field where it would be difficult to combat cutworms on account of the heavy rainfall which promptly destroys the efficiency of any poison which can be applied. Later it was found that seed planted in small nursery beds could be protected by hand picking and other methods used in cabbage culture, and from one of these plats 5 by 75 feet enough seedlings were secured to plant an acre with the rows 2 feet apart and the plants 1 foot apart in the row. This acre is now in good condition, and practically no replanting has been necessary. After one or two trials, seed planted in rows at the distances desired for the permanent field were grown in poor soil that had been carefully fertilized, so that it is now believed that the planting in seed flats and nursery bed is unnecessary, if a time is chosen to plant when the cutworms are not plentiful. This last can be determined by observation.

As it was realized that the quickest way to get these results to planters interested in saving on their feed bills was by local demonstration, it was decided to furnish seed and assistance in planting, together with any work necessary in combating pests, to anyone who would prepare an area of sufficient size to make it worth while. At the present time these cooperative planting projects are under way in a number of places, including a homestead in Laupahoehoe, a plantation, a school attended by over 100 boys from different parts of the island, a tract owned by a cooperative planters' association at "Twelve Miles" on the Volcano Road, and two of the dairy farms in the Glenwood district. As these plantings are at elevations ranging from sea level to 4,000 feet, they will give an idea of the adaptability of alfalfa to the different climates on this island.

POTATOES.

Plantings of Irish potatoes made at various times throughout the year have shown that yields of 100 bags (100 pounds each) or more to the acre can be obtained when planting is done in the two seasons beginning in July and August and in February and March. The table given below shows the results obtained from a variety test on plats of 240 square feet started in the early part of September, 1917:

Variety test of potatoes.

Variety.	Yield from plat of 240 square feet.	Estimated acre yield.
	Pounds.	*Bags.*
Hamakua Hybrid (light variety)	59.5	108
Hamakua Hybrid (dark variety)	51.2	93
Portuguese Red	48	87.2
Eureka Extra Early	33.7	61.3
State of Maine	23.1	42
Vermont Gold Coin	19.4	35.7

The first three of the above-named varieties seem to be better adapted to the local climatic conditions and are more blight resistant. The last three consistently give lower yields, although reported to be blight resistant in the eastern part of the United States.

That the Hamakua Hybrid potato will produce as well on larger areas as on the small plats at the experiment station has been demonstrated by Mr. Yamanaka, a cane planter from "Nine Miles" on the Volcano Road, who planted 4 acres within a half-mile of the Glenwood substation and secured 408 bags of potatoes, practically all of which were of marketable size. Mr. Yamanaka now has an increased area in potatoes, and others in the Glenwood district have planted from 5 to 10 acres. The indications are that the potato industry of this region will be considerably increased in the near future.

FIBER CROPS.

Trials have been made with sisal, New Zealand flax, hemp, flax, and Manila hemp in an effort to find some crop to serve as the foundation of a fiber industry and bring into intensive and profitable cultivation some of the areas near Glenwood which can not be used for sugar-cane cultivation. With the exception of Manila hemp, all these crops have shown some promise, the flax having made an even growth and attained a height of about 3 feet.

POULTRY.

Records of pure-bred stock of Single Comb White Leghorns and Rhode Island Reds, the breeds of poultry kept at the substation, and individual trap-nest records have been continued as in past years in order to maintain high egg-laying strains by selection and to secure hatching eggs for distribution throughout the island. An artificial brooding system was built into two houses capable of housing 350 chicks at one time, and in these houses the chicks from the station incubators and chicks sent to the station for rearing have been placed. One new incubator was obtained, and 600 eggs can now be set at one time in the station incubators. A floor has been put in a house 32 by 16 feet, and this is being used for the chicks after they come from the brooders and before they are able to resist the diseases which attack them if they are allowed to run on the wet ground. Three hundred pullets hatched during the last year are beginning to lay.

Because of the prohibitive prices on imported poultry feeds, a great many farmers have disposed of their stock, and unless some of the feeds necessary can be grown on the farms those who still remain in the business may be forced to do the same. Trials are being made with grain crops such as corn, buckwheat, oats, sunflower, sorghums, and certain varieties of beans, and it is thought if some of these can be successfully grown and fed in connection with such green feeds as rape, kale, alfalfa, and clover that the imported feeds can be eliminated.

EDIBLE CANNA.

Edible canna can be used as a substitute for potato and makes an excellent food for swine. The tops, growing to a height of 8 feet or more, were fed with success to large and small pigs when the leaves and stalks were cut into 8-inch lengths and fed immediately after cutting. The entire plant is relished by hogs, which thrive on it with little other feed besides waste from the house. Plats of edible canna were planted and cultivated at the substation last year and distributed to those who wished to plant.

UPLAND RICE.

Three varieties of upland rice were planted. Two of these did not germinate, but the third is in good condition, and if some seed can be matured which will be better acclimated, the growing of this food can be introduced in the Glenwood region.

HOG FEED PRODUCTION.

That there is a possibility of raising hogs economically near Glenwood is indicated by the growth of peanuts, cassava, and edible canna at the substation. The roots of the first two and the entire plant of the last make a sufficient variety of fattening feeds to mature hogs, especially when they are pastured on alfalfa. Pure-bred hogs are being kept by four farmers in Puna, and as they have had little trouble with sickness in their herds, it appears that a good return for time and money can be realized if the planters can raise their own feeds. Approximately 1,400 pounds to the acre of peanuts in the shell was secured at the substation, while the edible canna has produced tubers at the rate of 31 tons to the acre. Yields of cassava have not been definitely ascertained, but its growth at present is promising.

BAMBOO GRASS.

Bamboo grass, a promising feed for dairy cows, has yielded over 7 tons of green feed to the acre from a 6-weeks' ratoon growth, and since it is relished by cattle, even when mature and seemingly too coarse to be appetizing, it may become a valuable feed in this region.

SWEET POTATOES.

Two varieties of sweet potatoes, the Madeira and New Era, were planted in May, 1917, and after 8 months' growth produced 90 and 125 bags of 100 pounds each to the acre, respectively. As lack of warm weather and too much wet weather seem to retard the growth of sweet potatoes in this district, they make a less profitable crop than Irish potatoes.

VEGETABLES.

Seed of 40 varieties of vegetables were obtained from a mainland seed firm and compared with similar lots of seed bought in Honolulu and on the local markets. Brussels sprouts, cabbage, carrots, salsify, cress, endive, leek, lettuce, turnips, radishes, and asparagus all made a good growth from the seed obtained in the three places, and can apparently be grown successfully here, while most other vegetable crops easily grown in the lower elevations either do not germinate or make too slow a growth to be promising.

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